Hygiene and Public Health

Whitelegge and Newman

MANUALS FOR

STUDENTS OF MEDICINE.

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HYGIENE

AND

PUBLIC HEALTH

BY

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NEW EDITION, REVISED, ENLARGED, AND IN GREAT PART REWRITTEN

ILLUSTRATED.

CASSELL AND COMPANY, LIMITED

LONDON, PARIS, NEW YORK & MELBOURNE. MCMV

First Edition *August* 1890.
Revised *January* 1893, *December* 1893, 1894, 1895, 1896, 1897, *Jan*
Reprinted *October* 1899, Revised *June* 1901. Reprinted 1902,
New Revised Edition, 1905.

PREFACE TO THE NEW EDITION.

IN view of the great advances in the science and practice of Public Health since the first appearance of this Manual in 1890, the present edition (the tenth) has been revised, rearranged, and, where necessary, rewritten. In recent years many important additions to the official duties of Medical Officers of Health have been made, and fuller application of scientific knowledge is now required in preventive medicine. The object of the Manual is mainly to present a concise summary of the present position, for the purposes of the Medical Officer of Health and of the student.

B. A. W.
G. N.

August, 1905.

CONTENTS.

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INTRODUCTION.

PUBLIC HEALTH administration rests upon a wide range of sciences, almost all of which are in a progressive stage. The object of this elementary Manual is to summarise the more important practical applications of these in preventive medicine, and especially in the work of Medical Officers of Health, under present conditions; and where competent authorities differ in opinion or practice, to give prominence to official views generally accepted rather than to those of individuals. Readers who desire fuller technical detail will turn to special books of medicine, epidemiology, bacteriology, chemistry, physics, meteorology, geology, engineering and statistics; to the official publications of the Local Government Board, the Registrar-General, and other Government medical services at home and abroad; to the Reports of Royal Commissions and Departmental Committees; to the Reports of Medical Officers of Health; and to

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the technical *Journals* and the *Transactions* of the many learned societies concerned with Public Health.

Any review of such a field must, it is obvious, in many points be tentative and provisional. Improved methods and appliances, fuller and later statistics and research, and new conceptions, are brought forward year by year. These, together with further legislation, are recorded in the current literature of the subject. Finally, whilst care has been taken to furnish a reliable and comprehensive statement in the present volume, it cannot be too clearly understood that practical work in administration, in the laboratory, and in the hospital, is essential to a thorough grasp of many of the principles discussed in the following pages.

CHAPTER I.

AIR.

In 100 volumes of pure dry air there are, approximately, 21 of oxygen, 74 of nitrogen, and 5 of argon. There are also other gases in much smaller proportion In practice, however, air is never quite pure or dry, and it is therefore necessary to take account of watery vapour, dust, and gaseous impurities of local origin.

Oxygen ranges from 20·99 in volume per cent. in sea or mountain air to 20·7 in crowded rooms, 18·3 in ill-ventilated mines, and 16·5 in expired air. It is lessened by respiration, by combustion, by oxidisable organic effluvia, and by fog; but it is increased by vegetation and by rain. The average in the open air of towns may be taken as 20·96 volumes per cent.

Ozone, a more active form of oxygen, with the molecular formula O_3, instead of O_2, is an irrespirable gas readily reduced by oxidisable matter. It is only an occasional component of air, and is never present in more than minute traces, difficult of exact measurement. The proportion is greatest after thunderstorms, always higher on the coast than inland, and usually higher with S.W. rather than N.E. winds.

Nitrogen and argon are inert, and, from the point of view of public health, may be looked upon as diluents only.

Carbonic acid gas (CO_2), said to be absent from desert air, varies from 3·0 per 10,000 in purest mountain or sea air to 20·0 or even 30·0 parts in 10,000 in crowded rooms. In fresh open air it is stated to be, as a rule, 4·0 per 10,000, but this figure based upon Pettenkofer's process, appears to be too

high, and more exact measurement points to 3·0 per 10,000 as the correct standard. The proportion is greatly increased by expiration, for in expired air there is not infrequently as much as 450 parts per 10,000 (4·5 per cent.) The proportion of CO_2 in air is also increased by combustion, putrefaction, and fog, and it is diminished by vegetation, rain, high winds, and, of course, by ventilation. At great elevation the proportion is increased, owing possibly to the complete oxidation of organic matter (*Angus Smith*). Both carbonic acid and organic matter are greater in the air of towns than in the country, and in day air than night air. In railway tunnels Clowes found an average of 14 parts of CO_2 per 10,000, and on one occasion as much as 28·8 parts.

Ammonia salts in air, like carbonic acid gas, are due mainly to animal exhalations and putrefactive processes. Fresh air contains from 0·03 to 0·1 mgr. of carbonate or nitrate of ammonia per cubic metre, but in crowded rooms, or, for example, over middens, there may be 0·50 mgr., or even more. The variations are generally parallel with those of carbonic acid, and are similarly affected by weather.

Marsh gas or **methane** (CH_4) is met with in the air of coal mines and marshes. In the former case the proportion may be sufficient to destroy life by the exclusion of oxygen, but as much as 300 parts per 1,000 can be breathed with comparative impunity. If present in certain proportions it forms an explosive mixture with air.

Carbonic oxide (CO) is present in minute quantity in the air of towns, but in larger degree in, say, that of a railway tunnel. Coal gas contains from 4 to 12 per cent., but "water gas"* and "producer

* Under various names gases of this nature are now largely made and supplied to the public, both separately and as an auxiliary to an ordinary coal gas supply. They have, naturally, little lighting power, but can be

gas" as much as 40 per cent. Carbonic oxide is found as a product of imperfect combustion, particularly of charcoal, and cast iron stoves or burners may give it off in considerable quantity. Air containing 0·05 parts per 1,000 causes unpleasant, and eventually poisonous, symptoms in persons inhaling it. Less than a gramme of CO may kill a man (Oliver). The toxic properties of carbon monoxide are due to the fact that the gas enters into direct combination with the hæmoglobin of the blood, forming with it an extremely stable compound, making the blood useless for respiratory purposes. Persons thus poisoned die, therefore, simply from want of oxyhæmoglobin.

Sulphurous acid (SO_2) is another product of combustion, and traces of it are found in town air, least in clear breezy weather, most during fog and under anticyclonic conditions. Stoves and gas burners are the chief sources of SO_2 in the air of rooms

Sulphuretted hydrogen (H_2S) may occur in the air of marshes, in and near excavations, in collections of refuse or decaying vegetable matter, in sewer gas, and in chemical works and their waste heaps.

The inhalation of H_2S is followed by more poisonous results than is commonly supposed. An atmosphere containing 0·7 to 0·8 of H_2S in 1,000 litres of air is dangerous to human life, while air containing 1 to 2 per 1,000 parts destroys in a few minutes. When only minute quantities are present, vertigo, headache, and malaise are produced. Two types of poisoning occur, namely, that resulting in sudden death due to the action of H_2S on the respiratory nerve centres, and that resulting in slow

charged with oil-spray so as to be equal to ordinary gas, and for certain trade processes luminosity is not required. Their use calls for great care in gas fittings, and as a further precaution the gas should be "odorised," that is charged with some strong-smelling substance. In certain Acts authorising works of supply for "Mond gas," a limit of 14 per cent. of CO is imposed.

poisoning and death by asphyxia in addition to nervous phenomena.

It may here be stated that the various constituent parts of air are not chemically combined, but only mechanically mixed. The proofs of this are (*a*), that the relative proportions of oxygen and nitrogen present in air are not those of their combining weights, or of any simple multiple of those weights; (*b*), if air be artificially made by mixing oxygen and nitrogen together in proper proportions, no change of volume or temperature takes place as would be found had chemical combination occurred; and (*c*), if air and water be shaken together the water dissolves some of the air, which can be subsequently expelled by boiling, when the air which is expelled will be found to contain 14 per cent. more oxygen, which signifies that the atmosphere is not a stable chemical compound.

Physical properties.—(1) *Weight.* At a temperature of 32°F., the barometer being at 29·9 inches, 100 cubic inches of air weigh about 32·5 grains, and a cubic foot, 573 grains. (2) *Compression and expansion.* The stratum of atmosphere near the earth's surface is more dense because more subjected to pressure than the stratum remote from the earth's surface. The air is subject to Boyle and Marriotte's law: *the temperature remaining the same, the volume of a given weight of air is inversely as the pressure which it bears.* Under extreme pressure, with very low temperature, we now know that it may be liquefied (Dewar). The converse of compression is also true, and air is capable, in common with other gases, of expansion. This, too, follows a law, that of Charles: *the volume of a given weight of air at a constant pressure is proportional to its absolute temperature*, or, in other words, if the volume remains unaltered, the pressure varies as the temperature, and if the pressure remains constant the volume varies as the

temperature. The increase of the unit of volume of a gas for one degree of temperature, that is, from zero to one degree, is termed the *co-efficient of expansion*, and is practically the same for all gases ($\frac{1}{273}$ of their volume). (3) *Diffusion.* If two different gases in receivers be brought into communication with each other, they will diffuse the one into the other, and similar diffusion occurs in the atmosphere According to "Graham's Law" *the diffusibility of two gases varies in inverse ratio of the square roots of their densities.*

Bacteria in air vary in number and species according to certain external circumstances, of which the following are the chief, namely, the pollution of the air, the dampness of surrounding surfaces, gravity, and various seasonal and meteorological conditions.

(*a*) *The pollution of air.* It was Tyndall who in 1878 first pointed out that dust in air might carry micro-organisms ("the raft theory"), and that, other things being equal, dusty air contained more bacteria than dust free air. Since that time Haldane and others have confirmed this by examination of the air of workshops, schoolrooms, etc. In open fields, free from habitations, few bacteria are present, and the same is true of mountain and sea air; in towns or crowded rooms the reverse is the case. Miquel found an average of 455 bacteria per cubic metre in the park of Mont Souris, but an average of 3,910 in the Rue de Rivoli, and 79,000 in a hospital ward. Haldane found 8 per litre in a dressmaker's workroom, but 850 per litre in a dusty rope-maker's room; Graham Smith found 32 per litre in the dining room of the House of Commons, and 1 per litre in the open air of the Terrace; and Andrewes, investigating the air of the Central London Railway (underground tube), found 12 per litre on the lift and 21 per litre on the platform. Carnelly, Haldane, and Anderson found 6 bacteria per 10 litres in open air, 85 in houses of four

[illegible] in houses of two rooms, and 580 [illegible] A polluted or [illegible] contains many bacteria [illegible] there seems to be no [illegible] An atmosphere may [illegible] free from bacteria, [illegible] offensive trades, railway [illegible]

(b) *The dampness of surrounding surfaces.* Air [illegible] contains more bacteria as a rule [illegible] damp clay soils. Rain and snow also [illegible] number of organisms in air. It has [illegible] proved that air contained within a moist [illegible] is almost germ-free. Hence the comparative absence of bacteria in expired air in ordinary quiet respiration, though in the act of coughing, sneezing, or vomiting organisms may be present in the expired air (Flügge). Haldane, Andrewes, and others have shown that the same principle applies in a sewer, the air of which frequently contains fewer organisms than that of outside air, the species found belonging not to the sewage but to outside air. This is also the explanation of the retention of bacteria in sputum (the tubercle bacillus), or excreta (the typhoid bacillus), so long as these materials remain moist.

(c) *The influence of gravity* operates upon microscopic cells in the same way, of course, as upon other particulate matter. Hence, fewer bacteria are found at high altitudes or on the tops of lofty buildings. Binot did not find a single microbe in 100 litres of air collected at the summit of Mont Blanc. Miquel found 28 bacteria per cubic metre on top of the Pantheon, and 750 at the street level; and Graham Smith found that at the top of the Clock Tower of the Houses of Parliament in London there was only about one-third of the number of bacteria found at ground level.

(*d*) *Seasonal and meteorological conditions* also exert an influence upon the number of bacteria found in air. The seasonal maximum in the open air seems to occur about midsummer, and the minimum about the middle of winter, but in hospital wards and houses the reverse occurs, owing no doubt to ventilation. Air currents and wind, of course, exert a marked influence, as also do rain and snow. Direct sunlight possesses considerable bactericidal power, and thus reduces the number of air organisms.

Unlike the organic matter and carbonic acid, the number of microbes in the air of *crowded rooms* is dependent rather upon habitual ventilation and cleanliness than upon the conditions at the time of observation. They are not due, as we have seen, to respiration, or as a rule to want of cleanliness of persons or clothing, but are derived from the walls, ceiling, and floor of the room itself, especially if these are porous and absorbent, and if made to vibrate and thus create dust. As to the nature of the microbes found in the air, little that is definite can be said. Their variety is considerable, and for the most part they are saprophytes and harmless to man, but they may include putrefactive organisms, and under certain conditions the specific germs of disease. Under exceptional conditions bacilli of tubercle and typhoid fever have been isolated from air, though it is certain that air comparatively rarely contains pathogenic germs. Air-borne disease is, however, an established fact.

Spores of moulds, though more bulky than most other air-borne organisms, are less readily deposited. Other low forms of organisms and pollen may also be found, and may be the source of certain forms of disease (hay-fever).

Dust.—Aitken found the number of dust particles per cubic inch of air to range from 2,000 in the

open country to 3,000,000 in towns, and 30,000,000 in rooms. Apart from living organisms, dust consists chiefly of mineral particles, and of formed or unformed organic matter of vegetable or animal origin, *e.g.* epithelium scales, pollen, or particles of flax, wool, or cotton.

Indoor dust contains more organic components than that of the open air, although open fires add largely to the mineral part. The heavier particles subside readily in still air, the lighter more slowly, but practically deposition is always taking place, even in closed rooms and spaces, since air carrying dust is constantly passing in or out through crevices with variations of temperature and pressure. Hence the only dust-proof spaces are those which are kept hermetically sealed or in which there is provision for free entry of air through a dust-filter, as, for example, a closed bookcase, the back of which consists of baize or similar material.

Respiration. — Respiration abstracts oxygen from air and adds carbonic acid gas, water, organic matter, and a little ammonia. An average adult gives off about 0·6 cubic foot* of carbonic acid per hour, or 17 litres, of which perhaps about one-fiftieth part is yielded by the skin (*Regnault*). The amount is less in women, children, and aged persons, but more in animals, such as oxen or horses, which give off about three times as much CO_2 as does man.

Expired air, as we have seen, contains about 4·5 per cent. of carbonic acid, and only about 16 per cent. of oxygen. As a rough average it may be stated that 10 oz. of watery vapour are given off by the human lungs in 24 hours, and 20 oz. by the skin. In health, expired air contains few, if any, microbes, but much organic matter, the nature of

* 0·56 during sleep; 0·78 when awake. (*Pettenkofer.*)

which is very imperfectly known. It is nitrogenous, oxidisable, molecular, and probably exists in combination with water, since it is readily absorbed by hygroscopic objects. It is precipitated from solution by silver nitrate, blackens on ignition, reduces potassium permanganate, yields ammonia on distillation with alkaline permanganate, and has a fœtid smell. Unlike carbonic acid, organic matter diffuses sluggishly through the air of a room, and is slowly destroyed by fresh air. It promotes the growth of micro-organisms, in which respect it appears to differ from CO_2, and milk, meat, or other foods in contact with it readily become tainted. Both carbonic acid and organic matter are increased after exercise.

Combustion.—Coal when burnt gives off—(1) Carbonic acid, together with carbonic oxide unless the combustion is complete (it is estimated that each ton of coal burnt represents nearly 3 tons of CO_2 added to the atmosphere); (2) Sulphurous and sulphuric acids (1·5 per cent. sulphur exists in coal); carbon bisulphide, ammonium sulphide, and sometimes sulphuretted hydrogen; (3) Water; (4) Fine particles of carbon and tarry matter.

Coal gas yields similar products, but there is little free carbon or organic matter. The sulphur in gas should not exceed 20 grains per 100 cubic feet. The Alkali Works Regulation Act (1881) provides that not more of the acid gases of sulphur and nitrogen than the equivalent of 4 grains of SO_3 per cubic foot of air, gas, or smoke, must escape into the atmosphere.

Wood yields little of the sulphur compounds. Oil and candles give scarcely any, but they increase the organic matter in the air.

The gaseous products, especially carbonic acid, are rapidly diffused by air-currents; but the suspended particles diffuse slowly, and are not as a rule found

The bottle, having been cleaned and *dried*, is filled with sample air, either by means of a bellows, or other dry method. Moisture is held to invalidate the result. Sixty c.c. of clear lime-water are put into the bottle, the stopper is inserted and the air thoroughly washed with lime-water by means of vigorous shaking. The carbonic acid combines with lime and forms a milky precipitate of carbonate of lime; the loss of strength of the lime-water therefore measures the amount of carbonic acid present. After the bottle has stood at rest for a few hours, 30 c.c. of the lime-water are removed for analysis. It is not possible to collect the whole of the 60 c.c., nor would there be any advantage in doing so.

It only remains to determine by means of the oxalic solution the amount of lime present in the lime-water before and after the process, and from the loss to calculate the proportion of carbonic acid in the known volume of sample air. The determination of the "causticity" of the lime-water (that is, the amount of caustic lime it contains) is made by a simple process of alkalimetry. Oxalic solution is dropped from a graduated burette into a measured quantity (30 c.c.) of lime-water, until the exact point of neutralisation is reached. Several "indicators" are available for the recognition of this point. If a drop of the lime-water is removed from time to time and put in upon turmeric paper, it will give a brown stain as long as any caustic lime remains unneutralised, but none when the neutralisation is complete. A still simpler indication is obtained by adding to the lime-water a few drops of a solution of "phenol-phthalein," which is decolorised as soon as all the lime is neutralised.

Example.—The capacity of the bottle is 4,840 c.c., and 30 c.c. of lime-water take respectively 38 and 31 c.c. of oxalic solution before and after the process.

The volume of air is 4,840 c.c. $-$ 60 c.c. $=$ 4,780 c.c. Since 30 c.c. lost 7 mgr. of lime, the 60 c.c. employed lost 14 mgr., and from data already given this corresponds to $14 \times 0{\cdot}4 = 5{\cdot}6$ c.c. of carbonic acid. Hence, the sample air contained (by volume) 5·6 parts of carbonic acid in 4,780 of air, or 1·17 per thousand.

Corrections must be made if the temperature deviates materially from 32° Fahr., or the barometric pressure from 30 inches of mercury. One per cent should be added to the result for every 5° above 32° Fahr. If the barometric reading is B, the result must be multiplied by $\frac{30}{B}$. Thus, if in the above example the temperature were 72° Fahr., and the pres-

sure 29·2 inches, the corrections would be as follows:—$1{\cdot}17 \times \frac{108}{100} \times \frac{30}{29{\cdot}2} = 1{\cdot}3$ part of carbonic acid per thousand.

2. *Haldane's method.*—A method has been devised by Haldane for determining CO_2 without using collecting jars, etc. He adapts a gas analysis apparatus consisting of a burette with a wide ungraduated portion and a narrow portion graduated in divisions of $\frac{1}{10000}$ part of the capacity of the burette. This is enclosed in a water jacket, and a control tube is used to correct for variations of temperature. The pressures under which the readings are made are found to be the same, before and after absorption, by measuring the level of the potash solution in the narrow tube. The graduated burette allows of 25 c.c. of air to be admitted for examination. Having collected the amount of air the CO_2 is absorbed in the caustic potash solution. After complete abstraction of CO_2 the volume of the air is again read off at the same temperature and pressure. The difference between the two readings gives the result in volumes of CO_2 per 10,000 of air.

3. *Angus Smith's Minimetric method and "Household" test.*—A certain amount of carbonic acid is needed in order to produce a cloud in a given volume of lime-water. The volume of lime-water being constant, the volume of air necessary to give a visible precipitate affords a simple inverse measure of the carbonic acid it contains. Half an ounce of clear lime-water is placed in each of a series of stoppered bottles of different sizes, and well shaken. The *smallest* bottle which shows any cloudiness indicates the proportion of carbonic acid present in the sample air, according to the following empirical scale :—

A ppt. in a bottle of	443	c.c. capacity indicates the presence of at least	0·4	parts CO_2 per 1,000
,,	356	,, ,,	0·5	,,
,,	299	,, ,,	0·6	,,
,,	259	,, ,,	0·7	,,
,,	228	,, ,,	0·8	,,
,,	204	,, ,,	0·9	,,
,,	185	,, ,,	1·0	,,
,,	157	,, ,,	1·2	,,
,,	128	,, ,,	1·5	,,
,,	100	,, ,,	2·0	,,

Adopting 0·6 per 1,000 as the permissible limit of carbonic acid, there should be no precipitate when half an ounce of lime-water is shaken in a bottle of 300 c.c. or $10\frac{1}{2}$ oz. capacity. The method is not very satisfactory or accurate.

Carbonic oxide, CO, may be determined quantitatively by eudiometry, or by exposing a measured

volume of air to a solution of cuprous chloride, which absorbs this gas. The loss in volume shows the amount of carbonic oxide present. On passing CO through palladium chloride solution a black precipitate of carbon is formed. Its presence may also be determined by Vogel's test with the spectroscope after using ammonium sulphide. A caged mouse is affected in 1½ minutes by air containing 0·4 per cent. of CO, and this may be used as a sensitive test (*Haldane*).

Oxygen is determined quantitatively by exposing a measured volume of air to a solution of alkaline potassium pyrogallate, which absorbs the oxygen. The analysis may be conveniently made in a graduated glass tube inverted over a mercurial trough; the tube having been filled with air, the pyrogallate solution is passed up into it through the mercury. All the readings must be taken at the same pressure.

Ozone is detected by its action upon potassium dioide. Strips of porous paper are steeped in a solution containing starch and potassium iodide, and then dried. These are exposed for a definite period to the air, care being taken to exclude sun and rain. Ozone causes a blue tint, the intensity of which is taken as indicating the amount of ozone according to a standard scale of tints;* the ozone liberates iodine from the potassium iodide, and the iodine strikes a blue colour with the starch.

Ammonia may be collected by aspirating a known volume of air through distilled water, and then determined (quantitatively as well as qualitatively) by Nesslerising (page 78).

* For several reasons this test is held to be inexact. The chief are (1) that nitrous acid and peroxide of hydrogen, as well as ozone, give the reaction; (2) that the conditions of exposure are not uniform—light, wind, humidity, and temperature all vary, and all affect the reaction; (3) some of the liberated iodine is volatilised, and some reacts again upon the potash to form inert iodide and iodate.

Nitrogen is determined with sufficient accuracy as the residue left when oxygen is removed by pyrogallate solution. The proportions of other gases are so small that their retention does not materially affect the determination of nitrogen.

Water, or rather aqueous vapour in air, may be measured by the hygrometer, by the spectroscope, or volumetrically by its absorption by sulphuric acid, etc.

It may occasionally be necessary to test for sulphuretted hydrogen, or for mineral acids due to chemical manufacturing processes. The former is detected by exposing strips of porous paper moistened with a solution of lead acetate, and noting the black colour due to formation of lead sulphide. Free mineral acids will redden moist blue litmus paper; and may be obtained for chemical analysis by aspirating the air through distilled water or solution of caustic potash.

CHAPTER II.

METEOROLOGY.

THE principal climatic phenomena requiring systematic record are: (1) Temperature of the air; (2) Pressure of the air; (3) Movement of the air; (4) Amount or degree of moisture in the air; (5) Ozone; (6) Rainfall; (7) Sunshine; (8) Cloud, mist, fog.

Temperature varies constantly, so that the reading at any one time has only a limited significance, and maximum and minimum registering thermometers are required for systematic record.

The *maximum thermometer* has a mercurial column, a detached portion of which serves as an index, being either permanently separated from the rest by a minute bubble of air (Phillips), or else detached afresh each time by means of a constriction near the bulb (Negretti), which allows the expanding mercury to pass, but renders the cohesion of the metal insufficient to draw it back upon cooling. The thermometer is kept horizontal, and the index is shaken back after each reading, ready for a new observation.

The *minimum thermometer* (Rutherford's) contains coloured alcohol. The index is a little metal rod included in the column, and is drawn back by capillary attraction as the column contracts, but allows the alcohol to flow past it when expanding. To set the instrument, it is only necessary partially to invert it, and let the index fall to the top of the spirit column. It is then replaced in the horizontal position.

If the instruments are read once daily, say at 9.0 a.m., they indicate respectively the highest and lowest temperatures attained during the previous 24 hours, irrespective of the time of occurrence.

Two sets of instruments are used, one for "shade" temperatures, *i.e.* the temperature of the air

itself, the other for "radiation" temperatures with free exposure to the sun.*

Thus are obtained for each day—shade maximum, shade minimum, sun maximum, grass minimum; and from these the daily, weekly, monthly, or yearly ranges, both in shade and with free radiation.

The *mean temperature* of the day is calculated in several ways :—

(*a*) By taking the mean of the maximum and minimum recorded temperatures. This is correct only in winter; at midsummer it is often more than 2° too high.

(*b*) By taking the mean of two readings at twelve-hour intervals: *e.g.* 9.0 a.m. and 9.0 p.m.

(*c*) By taking a single reading at 9.0 p.m.

(*d*) By taking hourly readings, or a continuous record, by means of photography. The mean of these is the true mean temperature of the day.

The weekly, monthly, and annual means are the averages of the daily means. Taking the average of a number of years, the daily minimum occurs at about 4.0 a.m., the maximum at 2.0 p.m. The annual extremes are in July and January respectively.

Proximity to the sea lessens the range of temperature and moderates its extremes, water having (as compared with land) a high capacity for heat, but being slow to radiate or absorb it. Elevation lowers the temperature, by facilitating radiation. The influence of latitude, of winds and ocean currents, and of aspect and exposure, is obvious. Some soils are "hot"—dry sands and hard rocks, for example—while moist clayey soils are "cold." A surface covered with vegetation radiates much more

* The former are placed in a louvred wooden box four feet above the ground. The "sun maximum" thermometer also is placed four feet above the ground; it has a blackened bulb, which is enclosed in a second glass bulb exhausted of air. The corresponding minimum instrument is supported upon a little wooden tripod, close to the ground.

rapidly than bare earth; at night a grass field is colder than a road.

Earth temperature, that is the temperature of the soil at fixed depths, is more uniform and less diurnally variable than atmospheric temperature. According to Ballard, when the temperature at 4 feet reaches 56° Fahr., infantile diarrhœa may be expected to become epidemic. Earth temperature, which is measured by Symonds' earth thermometer, varies but little, proportionately, from surface temperature, except that it is much more sluggish. At 24 feet of depth, however, it is almost the reverse of surface temperature, being highest in winter and lowest in summer (*Forbes*). Below 40 feet there is little annual variation in the temperature of the soil.

The radiation thermometers are affected principally by the degree of sunshine and the humidity of the atmosphere.*

Humidity involves rather complex considerations. Water evaporates into dry air, as into a vacuum, but the volume of the resulting moist air is greater than that of the original dry air. For example, a cubic foot of dry air at 60° Fahr. weighs 536·3 grains, and is capable of taking up 5·77 grains of water; the product, however, is not 1 cubic foot of moist air, weighing 542·1 grains, but 1·0176 cubic foot, and a

* The duration and intensity of **sunshine** are recorded by Campbell's or Jordan's apparatus. The former consists essentially of a glass sphere, which acts as a lens, and brings the rays to a focus at successive points upon a curved sheet of paper placed at the right distance. A burnt track is thus described for such time as bright sunshine continues. Jordan's sunshine recorder is a small flat circular box. The sunshine is admitted through a slit, and impinges upon sensitised paper, leaving a varying photographic record of its duration and intensity. In either apparatus the papers must be renewed daily, and in the latter the sensitised paper must be "fixed" by immersing it in water.

cubic foot of the same moist air weighs only 532·7 grains. At 32° Fahr. a cubic foot of dry air can take up only 2·13 grains of water; at 80° Fahr. it can take up 10·98 grains. Further, the capacity for moisture increases with the temperature, but much more rapidly.

Indeed, it may almost be said that, comparing temperatures which increase in arithmetic progression, the capacity of dry air for moisture at those temperatures increases in geometric progression. Taking 0·0° F. as a starting-point, the capacity for moisture (in other words, the weight of a cubic foot of aqueous vapour) doubles with successive increments of temperature, not departing greatly from an arithmetic series.

Temperature (Fahrenheit).	Weight of a cubic foot of vapour.
0°	0·55 grains
16°	1·09 "
33°	1·21 "
52°	4·39 "
73°	8·32 "
96°	17·68 "

As a rule, the water present is only about 70 or 75 per cent. of the amount required for saturation, but if the air is cooled, the same quantity of aqueous vapour may suffice to saturate it; and if the cooling is carried further some of the water will be precipitated as mist or dew. It will be understood, therefore, that, however dry the air may be, it always contains a certain proportion of water, and if cooled to a certain temperature will be "saturated" by that moisture; this temperature is called the *dew point*. "Super-saturated" air deposits its moisture only upon solid surfaces, and this is the cause of mists and fogs.*

* **Fog** is formed by the condensation of watery vapour on dust particles suspended in the air, which afford "free surfaces" on which condensation can occur. Such atmospheric dust probably consists of fine salt dust from the sea, meteoric dust, condensed gases, combustion dust, and particulate organic and inorganic matter. Aitken holds that the

Humidity is measured by **hygrometers** of various kinds.

Daniell's, now rarely used, consists of two dependent glass bulbs, connected by a tube bent twice at right angles. One bulb is of black glass, and contains a thermometer, the stem of which is visible in the tube above; the other bulb is covered with linen. Both bulbs contain ether. A little ether is dropped on the linen coating, and by its evaporation lowers the temperature of that bulb, so that ether distils over from the blackened bulb. This causes the temperature of the latter to fall; as soon as it sinks to the dew-point the black surface is dulled by deposit of atmospheric vapour, and this temperature is instantly read off by means of the contained thermometer.

Regnault's is somewhat similar, but the black bulb is replaced by a more sensitive bright silver cup, and the distillation is brought about more conveniently and rapidly by means of an aspirator.

Dines' consists of a plate of black glass, covering a small chamber containing the bulb of a thermometer. Cold water is passed through this chamber until the dew-point is reached and the glass becomes dull; the current is then stopped, the temperature gradually rises, and the thermometer is read at the moment when the cloud disappears.

Saussure's, which has the advantage of giving the relative humidity directly, consists of a human hair, fixed at one end and stretched by a light weight attached to the other. It passes round a movable axis which carries a finger pointing to a graduated arc. The hair, which must be uninjured and free from oil, elongates with moisture and contracts as it becomes dry; and in so doing rotates the axis and the indicator. The instrument has to be graduated empirically by exposing it first to perfectly dry air, and then to air saturated with moisture, and making the respective positions of the index the 0 and 100 points upon the graduated scale.

The *wet and dry bulb* hygrometer is usually employed. Two ordinary thermometers are fixed side by side, one of them having its bulb covered with muslin,

earth's atmosphere is greatly polluted with dust, produced by human agency, rising by heated strata of the air, and forming the "free surface" for condensation, even though the air be not saturated. The higher the humidity and the higher the vapour tension, when the air is not saturated, the greater is the amount of moisture held by the dust particles. Town fogs and smoke fogs may be dry, and are largely constituted of particles of unconsumed carbon.

kept wet with distilled water; a tail of the muslin dips into a vessel of water so as to make good the loss by evaporation. If the air is saturated with moisture, no evaporation takes place, and the two thermometers give the same reading. If it is not saturated, evaporation lowers the temperature of the wet bulb.

From the wet and dry bulb readings the *dew-point* can be calculated, and from the dew-point the weight of water present in the air. The dew-point is determined by calculation,* or, more conveniently, by reference to Glaisher's Tables,† in which the results are given for all ordinary values of both readings. The dew-point being known, the next step is to find the **relative humidity** of the air, which is always expressed as the percentage of total saturation. For this purpose reference is made once more to hygrometric tables, giving the weight of a cubic foot of vapour at each temperature; and the relative humidity =

$$\frac{\text{weight of cubic foot of vapour at the dew-point}}{\text{weight of cubic foot of vapour at dry-bulb temperature}} \times 100,$$

since the numerator is the weight actually present, and the denominator the weight which is required for complete saturation at the dry-bulb temperature.

In practice none of these calculations are necessary, since Glaisher's Tables give the relative humidity corresponding to all ordinary readings of the wet and dry bulb thermometers. This is by far the most important hygrometric datum, the absolute weight

* By the use of Apjohn's Formula, $f'' = f' - \frac{t - t'}{87}$, where t and t' are the dry and wet bulb readings respectively, f' the elastic tension of vapour corresponding to t' (as ascertained from a table of tensions), and f'' the tension of vapour at the dew-point. Having thus found the value of f'', the temperature corresponding to it in a table of tensions is the dew-point.

† Based upon the "Greenwich Factors," or "Glaisher's Factors," a different factor being employed for each temperature. If D is the factor corresponding to the dry bulb temperature, the dew-point is $t - D(t - t')$.

or tension of vapour present, and even the dew-point, being of minor interest. The relative humidity is an inverse measure of the drying effect of air. The capacity for taking up moisture increases with the temperature, but far more rapidly, so that the mere difference between the dew-point and the air temperature is no criterion of the humidity.

Aqueous vapour intercepts some of the sun's luminous rays, and very greatly impedes the radiation of non-luminous rays from the surface of the earth into space. Hence the difference between the sun-maximum and grass-minimum temperatures is chiefly dependent upon the humidity. The intensity of radiation at high altitudes is largely due to the absence of aqueous vapour. In Arctic regions the unimpeded solar radiation has been known to boil the pitch in the seams of ships which were surrounded by ice.

Humidity comes into question also in connection with ventilation, the aim being to keep the air of rooms as near as practicable to the accepted *optimum*, namely, 70% of saturation. Hence in heating by convection it is desirable to moisten the air, and for certain trade processes in which air is steamed limits of relative humidity are imposed by law.

Evaporation from moist surfaces is regulated by the temperature of the water, the temperature of the air, the humidity of the air, and the wind. It is more rapid from moist soil than from water; and deep-rooted crops, such as wheat, dry the soil to a greater depth than grass. No satisfactory instrument (*atmometer*) has been devised for measuring evaporation, owing to the difficulty of excluding rainfall while allowing free exposure. A rough estimate may be obtained by exposing a measured volume of water in an open dish of known area, and deducting from the final measurement the ascertained rainfall. Another

plan is to shelter the atmometer from rain by a cover, but this necessarily lessens the evaporation. Symons found that at Lea Bridge the mean annual evaporation per square inch of water-surface was 21 inches, the rainfall being 25 inches. In exceptionally dry years it exceeds the rainfall.

Atmospheric pressure is measured by barometers. *Mercurial barometers* consist essentially of a glass tube some 36 inches long filled with mercury, and then inverted over a mercurial trough. The tube being vertical, the mercury sinks until the column is of just sufficient height to balance the atmospheric pressure acting upon the free surface of the mercury in the trough. The vertical distance between the two mercurial surfaces exactly measures the pressure of the atmosphere in terms of mercury. The level of the top of the column is read off against a fixed scale, but as the level of the mercury in the cistern also changes slightly with every change of pressure, it is necessary to take this into account.

In Fortin's barometer the cistern has a leather bottom, which can be raised or lowered by means of a fine screw, until the surface just touches a fixed ivory point. After this adjustment of the cistern to a constant standard level, the upper level is read upon a scale marked upon the brass casing of the tube.

In the Kew barometer the necessity for the adjustment is obviated by graduating the scale in nominal inches, which are shorter than true inches, and exactly correspond to the displacement caused by a change of pressure to the extent of one inch of mercury. A single reading therefore gives the true vertical height of the column.

In the siphon barometer the cistern is dispensed with, and the tube is of U shape, one arm being short and open at the end. Both levels are read upon a scale. The movement in either arm is little more than half that occurring in a cistern barometer.

The ordinary wheel-barometer is a syphon barometer, the movements being transmitted by a string from a float upon the mercury in the open tube to an axis which carries a long finger like that of a clock.

Greater accuracy in the reading is obtained by the use of the "vernier," a small movable scale which slides upon the principal scale (Fig. 1). If the barometer is graduated to $\frac{1}{20}$ inch divisions the vernier can be so graduated that 25 of its divisions correspond to 24 of those upon the other scale, and each division is therefore only $\frac{24}{25}$ of the length of the standard divisions. With sub-graduation the vernier will show differences of $\frac{1}{25}$ of $\frac{1}{20}$, *i.e.* ·002, or $\frac{1}{500}$ inch. When a reading is to be taken, the lowest mark on the vernier is accurately adjusted against the top of the mercurial column. If this level exactly corresponds with one of the divisions of the principal scale, the vernier correction is not needed; its lowest mark will coincide with the mark on the scale. If, however, the level of the mercury does not exactly coincide with a scale division, the vernier helps us to measure more accurately than is otherwise possible the fractional excess over the next division below. For this purpose we must follow the vernier scale upwards until we come to a mark upon it which corresponds more closely than any other to one on the fixed scale; calling this the xth mark, the correct reading is $\cdot 002 \times x$ inch above the scale mark next below the mercury level. For example, the mercury stands above 29·85, but below 29·90, as read on the fixed scale, and upon inspection it is

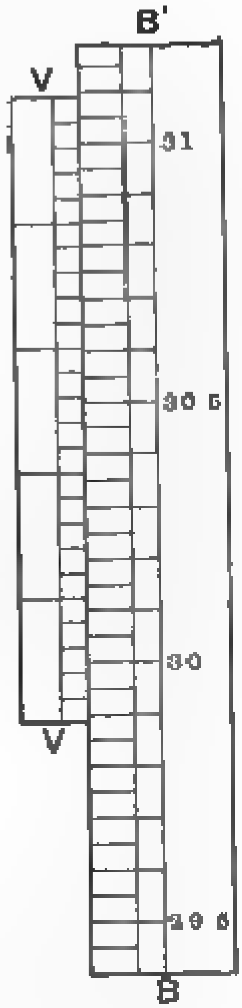

Fig. 1.—Barometer Scale and Vernier, showing a reading of 29·85 + 18 × ·002 = 29·886 inches.

found that the sixth vernier division corresponds with a division of the fixed scale. This shows that the fractional excess above 29·85 is 6 × ·002, or ·012 inch, and the true reading is therefore 29·862 inches. Had the 20th division of the vernier been the one which coincided with a fixed scale mark, the fraction would have a greater value, 20 × ·002 = ·04 inch, and the barometric reading would be 29·89 inches. A little consideration will make it clear that as compared to scale divisions we lose ·002 inch for every vernier division as we follow the marks upwards, until we have lost all the fractional excess over the 29·85 mark, and then the marks on the two scales will correspond.

The reading having been accurately taken with the aid of the vernier, it remains to apply certain corrections:—

(1) For "index error" *i.e.* inaccuracies in the scale.

(2) For "capacity" *i.e.* for the change in the cistern level, unless this is allowed for as already described. Practically, this correction is never called for in good modern barometers.

(3) For "capillarity," which tends to depress the column slightly.

These three corrections are special to each instrument, and Kew certificates give for each half inch a correction comprising them all

(4) For temperature, which affects the mercury, and also the brass or other scale. All readings are reduced to 32° Fahr. by means of a table giving corrections for each temperature.

(5) For elevation. It is customary to reduce all readings to sea-level *i.e.* the mean half-tide level at Liverpool. For this purpose it is necessary to know the exact height of the station and to refer to a table of corrections. Roughly speaking, the correction is about 1 inch for every 1,000 feet.

Owing to the high specific gravity of mercury, 13·5, a column of about 30 inches in height balances the atmospheric pressure, and there is the further advantage that the vapour-tension in the Torricellian vacuum

above the mercurial column is trifling. The density of mercury, however, renders the range of movement under varying atmospheric pressures small, and other liquids have been employed in order to secure greater sensitiveness of indication. Jordan's *glycerine barometer* is the most important of these; glycerine has a specific gravity of 1·26, and a column of 27 feet would about balance a mercurial column of 30 inches. A fall of 1 inch of mercury is represented by a fall of 10·7 inches of glycerine, and the latter is therefore far more sensitive. *Water barometers* have also been constructed, a column of 34 feet being required to balance 30 inches of mercury. These instruments are, of course, still more sensitive, and magnify the mercurial reading 13·5 times; but in addition to the disadvantage of their height, the vapour tension in the vacuum is a source of error that varies with the temperature.

Aneroid barometers dispense entirely with liquids, and measure the barometric pressure by means of the elasticity of metal. A small air-tight metallic box is (nearly) exhausted of air, and is so constructed that the top is slightly forced in when the atmospheric pressure rises, and (aided by a strong spring) comes out when the pressure falls. These movements are conveyed by levers, etc., to a finger moving upon a dial; the dial is graduated empirically by comparison with a standard mercurial barometer.

There are periodic and non-periodic variations of pressure, but the former are so completely masked by the latter in the latitude of England as rarely to be perceptible except in averages. There is a tendency to a daily curve, with a range of about 0·02 inch. There are two maxima, about 9 a.m. and 9 p.m.; and two minima, about 3 a.m. and 3 p.m. This slight curve is only noticeable in the rare absence of non-periodic changes; but in the

Tropics the daily range exceeds 0·11 inch, while in Arctic regions it vanishes. The annual curve in England is somewhat irregular, but has a maximum at the end of May, and a minimum at the end of October. It is very different in other countries.

Rainfall is measured by a *rain-gauge*, consisting of a copper funnel leading to a bottle or other receiver. The funnel has a sharp, circular rim, usually 5 inches or 8 inches in diameter, and its area in square inches is accurately known. The water collected in the receiver is measured in a graduated glass vessel, the divisions of which correspond to the fractions of an inch of rainfall. It is found that the amount collected is greatest at the ground level. Care must be taken to place the rim of the gauge perfectly level and to select an open site. "No object ought to subtend a greater angle with the horizon than 20° in any direction from the gauge" (*Scott*). Snow and hail may be melted for measurement by adding a known volume of warm water, which must be deducted from the total.

As regards the daily curve of average rainfall there are indications of three maxima, the principal of which occurs about 2 or 3 p.m. The annual curve varies with locality. In London and on the east coast of England the principal maximum is in October, and the minimum in February or March; but on the west coast January is the wettest month.

The average annual rainfall varies from about 20 inches on the east coast of England to 60 or 80 inches on the west coast of Ireland and Scotland; and at Seathwaite, in Cumberland, it averaged 154 inches during six years. The average for England is about 25 inches.

The rainfall does not often exceed an inch in one day in Great Britain, but enormous quantities are

recorded occasionally. At Camberwell, in 1846, 3 inches fell in $2\frac{1}{4}$ hours, and in Monmouthshire, in 1875, 5·36 inches fell in one day.

It is greatest on the westward slope of English mountains, owing to the humid westerly winds depositing moisture as soon as they are forced to ascend into colder strata. Haughton calculates that one gallon of rainfall, by its condensation from vapour into the liquid form, gives out latent heat sufficient to melt 75 lbs. of ice, or 45 lbs. of cast iron; and that on the west coast of Ireland the heat derived from the rainfall is equivalent to half that derived from the sun.

Wind may be measured, by *anemometers*, as regards either its pressure or its velocity.

Hooke's anemometer is a thin rectangular plate of iron, suspended from its upper edge, and set at right angles to the wind. The force of the wind is measured by the angular displacement of the plate. In Cator's anemometer the wind forces back a plate, the movement of which is resisted by graduated weights. A pencil connected with the plate records upon a chart moved by clockwork the displacement. In Osler's anemometer the principle is the same, but the weights are replaced by a spring.

Pressure anemometers have the advantage of recording gusts and sudden changes in wind-pressure. So far as velocity and pressure are comparable, it may be said that the pressure varies as the square of the velocity. If V = the velocity in miles per hour, and P = the pressure in pounds per square foot, then according to James,

$$V^2 = 200\ P.$$

Robinson's is the only one in common use. It consists of four light arms rotating in a horizontal plane around an axis, through which their movements are transmitted to a series of recording dials. Each arm has at its extremity a hemispherical cup, facing horizontally at right angles to the arm. In whatever direction the wind blows, the vanes

revolve, the resultant pressure upon the concave surfaces being greater than that upon the convex. It was formerly believed that the cups moved with one-third the velocity of the wind, and the index dials were graduated accordingly. It appears, however, that the proportion is greater than one-third, and has a direct relation to the size of the cups and the velocity of the wind.

Apart from the uncertainty as to the true value of the readings of each instrument, the records of different stations are not strictly comparable, since inequalities in elevation and in shelter from the wind are inevitable, and must materially affect the results. The position of the anemometer should be such as to secure the fullest possible exposure to wind from all quarters.

The average velocity of wind in Great Britain shows a daily maximum and minimum closely corresponding to those of temperature, about 2 p.m. and 4 a.m. The annual curve of average wind-velocity has a maximum in July and a minimum in December or January.

In *Beaufort's scale* the force of the wind is stated by arbitrary numbers, ranging from 0 (calm) to 12 (hurricane).

Force.	Beaufort Scale.	Miles per hour.
0	Calm	Up to 3.
1	Light air	8
2	Light breeze	13
3	Gentle breeze	18
4	Moderate breeze	23
5	Fresh breeze	28
6	Strong breeze	34
7	Moderate gale	40
8	Fresh gale	48
9	Strong gale	56
10	Whole gale	65
11	Storm	75
12	Hurricane	90

In England the velocity is, upon an average, about 8 miles per hour, and rarely exceeds 40. Local winds may be caused by geographical configuration—*e.g.* upon coasts and mountains. In normal conditions a wind blows at noon from sea to land, from plains to hills, but at sunset the directions are reversed. Winds increase in force with elevation.

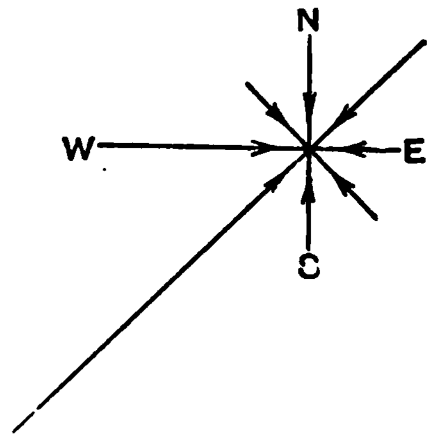

Fig. 2.—Wind-rose.

A "wind-rose" (Fig. 2) is a scheme showing the relative proportions of wind-observations from each point of the compass. The Greenwich wind-rose for 1861-70 was

N	NE	E	SE	S	SW	W	NW
10	12	7	7	8	33	15	7

If the readings of the barometer at any given moment at several stations dotted over a wide area, such as Europe, are recorded upon a map, and lines are drawn connecting together all the points where the same pressure prevails, we obtain a "synoptic chart," and these lines, or **isobars**, are found to assume very commonly certain typical forms (Fig. 3).

1. *Cyclones*, formed by concentric isobars, the lowest pressure being at the centre.

2. *Anticyclones*, the isobars being roughly concentric, with the highest pressure at the centre.

3. *Secondary cyclones*, formed by looped concentric isobars (the circle being incomplete, and thus failing to form a true cyclone) with lowest pressure in the centre.

4. *V-shaped depressions*, with lowest pressure in the interior, forming, for example, the angular intervals between adjoining anticyclones.

5. *Wedges* of high pressure—highest in the interior —inserted between two adjacent cyclones, and usually pointing to the north.

6. *Cols* or necks of comparatively low pressure between two adjacent anticyclones, like the pass or "col" between two Alpine peaks.

7. *Straight isobars.*

Cyclones, secondary cyclones, V-depressions, and

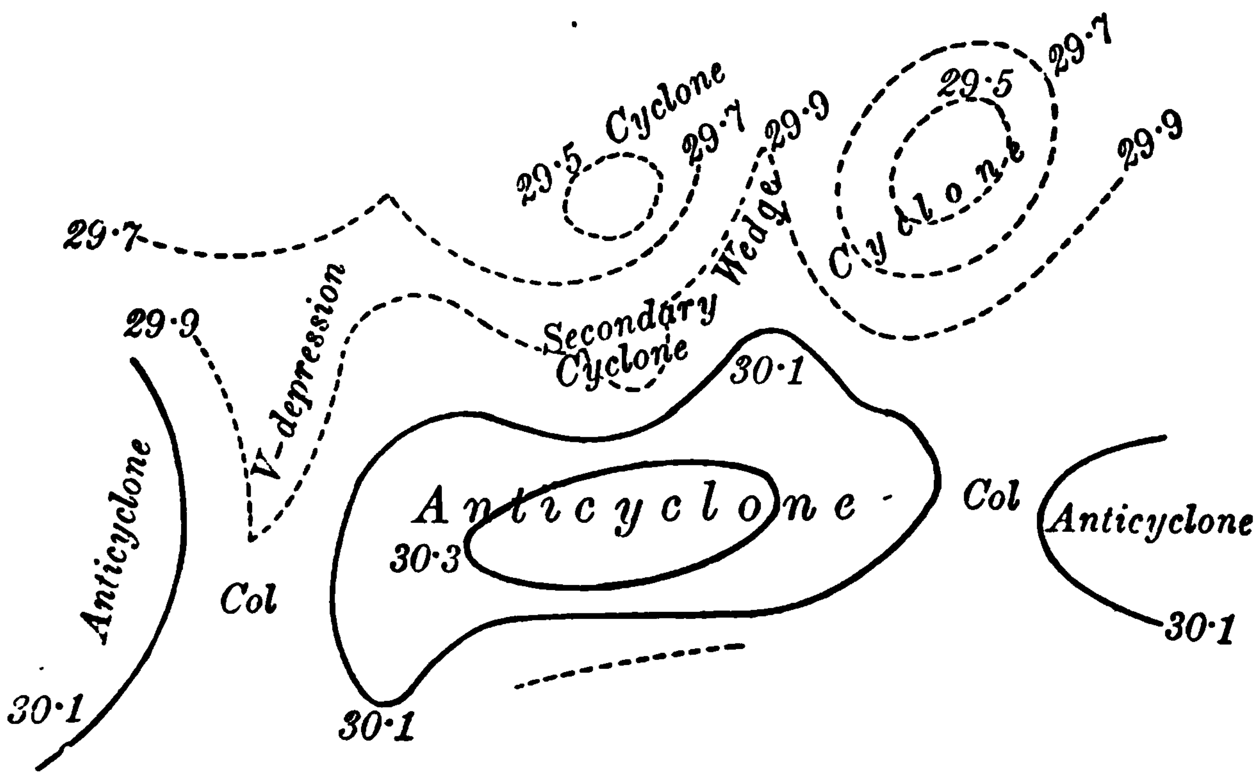

Fig. 3.—Distribution of Pressure over the North Atlantic, and parts of the United States and Europe, Feb. 27th, 1865.
(*After Abercrombie.*)

wedges, usually travel eastward at the rate of about twenty miles per hour, but anticyclones often remain stationary for days, weeks, or even months.

If the direction of the wind at each station is marked upon the synoptic chart, it will invariably be found that its direction is roughly parallel to the isobars, and that in anticyclonic areas (in the northern hemisphere) it describes a circle in the same way as the hand of a watch, while in cyclonic areas this course

is reversed.* The direction of the wind in these and in all other arrangements of isobars conforms to *Buys-Ballot's law*—that an observer standing with his back to the wind always has lower pressure to his left, and higher pressure to his right.

The closeness of the isobars, or in other words, the rapidity of change of atmospheric pressure, forms the "barometric gradient," to which the velocity of the wind is directly proportionate.

Not only the force and velocity of the wind can be inferred from the arrangement of the isobars, but also the kind of weather prevailing at each station. The front part of an advancing cyclone is associated with rain, stratiform clouds, and moist, heavy atmosphere, while in its rear the opposite conditions prevail, namely, sunshine, clear "fresh" air, and cumulus clouds. Anticyclones are less intense, more stationary, and cover a wider area than cyclones. In front of them and at the centre are found sunshine, blue sky, haze, little wind, keen dry air, and free radiation, with great daily range of temperature. The weather changes which accompany secondary cyclones or V-depressions are the same as those of cyclones; wedges, like anticyclones, have fine weather in front and bad weather in their rear.

All these types are liable to break up or merge into new forms at any time, but it is often possible to "forecast" the weather in any given locality by learning from the synoptic charts the direction and velocity of cyclones approaching from the west.

Cyclones are often diverted from their course by meeting a coast line or mountain chain, or even an anticyclone; their course is not necessarily straight,

* The course of the wind is not exactly parallel to the isobars. The wind crosses the isobars obliquely, and may be described as blowing spirally into a cyclone and spirally out of an anticyclone.

nor their velocity by any means uniform. Lastly, their intensity—as measured by the steepness of the barometric gradient and consequent wind-velocity—may also change.

Cyclones are much more numerous than anti-cyclones. The centre of depression usually passes to the north of Britain, and hence it is more common for the wind to "veer" (or "go with the sun") than to "back." It is only necessary to imagine a watch (with its hand moving in the reversed direction) passing over a given point upon a map to understand the successive changes in the direction of the wind at that point, during the passage of a cyclone.

Climate is the condition of a country in relation to certain meteorological elements, viewed as to their effects upon animal or vegetable life. These elements are (*a*) distance from the equator, or latitude; (*b*) relative distribution of land and water; (*c*) altitude; (*d*) presence of ocean currents; (*e*) rainfall; and (*f*) wind. Proximity of mountain ranges and their influence upon the shelter from wind and on the rainfall, soil and its permeability to moisture, and vegetation, also exert an influence on climate. The climate of the British Islands is typically marine, being greatly influenced by its insular position and the Gulf Stream, which latter causes the "isothermal lines" (*i.e.* lines of equal temperature) of the North Atlantic Ocean to run from S.W. to N.E. Such a climate is essentially a temperate one, free from extremes of heat and cold, and yet marked by a high degree of atmospheric moisture. Rheumatism, lung affections, and other diseases directly or indirectly due to such climates therefore abound. It is customary to divide climates into Warm, Temperate, Cold, Marine, and Mountain climates, and in each of these disease bears some relation to the climate. Particularly is this true

of tropical or sub-tropical climates, in which malaria, dysentery, liver abscess, cholera, yellow fever, and a variety of tropical parasitical diseases find favourable conditions. At the same time much can be done by judicious living to enable the individual accustomed to one climate to live healthily in another.

CHAPTER III.

WATER.

Amount.—It is generally estimated that from 10 to 15 gallons of water per head per day are required for personal and domestic use, 5 to 10 gallons for municipal purposes and a similar quantity for trade processes, but all these items are liable to wide variation. About 20 to 30 gallons per head are supplied in most towns in Great Britain. The average daily amount taken in food is about half a gallon, but at least a pint of this is contained in solid food. Half a gallon more is used in cooking. Parkes suggested as a standard in a middle-class household 6 gallons per head for domestic washing, 5 for ablutions, including a sponge-bath, 6 for water-closets, 4 for general baths, and 3 for unavoidable waste.

Sources.—All natural waters are ultimately derived from the rainfall, which in its turn is due to distillation under the influence of the sun's rays from all humid portions of the earth's surface. Part of the rainfall is again evaporated from the surface upon which it falls, part flows along the surface to form streams and lakes. A third part sinks into the soil, descending through fissures or pores, until it reaches an impervious formation, and it then either finds its way laterally to the surface in the form of springs, or accumulates in the porous strata overlying the impervious layer, where it may be reached from the surface by wells. It has been found that upon sand or gravel surfaces as much as 90 per cent. or more of the rainfall sinks

into the ground, as compared with 40 per cent. on the chalk, and 20 per cent. on limestone, while upon clay scarcely any infiltration occurs. For obvious reasons the proportion is less in hilly districts, which offer greater facilities for surface-flow, and less in summer than in winter owing to excessive evaporation. Experiments upon a gravelly loam indicated a penetration of only 2 per cent. in summer and nearly 100 per cent. in winter.

In a memorandum dated December, 1897, addressed to District Councils, the **L.G.B.** observes:—

"The Council . . . should by careful inquiry make themselves acquainted with the sources, nature, and quality of the water supplies in all parts of their district, and, in every case in which the result of their inquiries is unsatisfactory, should take all such steps as may be within their powers, with the view of supplementing or improving the supplies. . . . Accurate information should be procured, if not already available, in such matters as the following:—

1. *Where water is derived from gathering ground or from springs.* Whether drainage from human habitations, farmyards, and the like finds its way directly or indirectly into the reservoir or to any part of the water service; and whether risk of access to the water of human excreta and similar refuse is likely to arise.

2. *Where water is derived from deep wells.* Whether surface or other water liable to be contaminated by drains, sewers, cesspools, and the like, reaches, or is liable to reach the wells. The existence and direction of fissures in the strata deserve a special consideration in this respect.

3. *Where the water is derived from shallow wells.* Whether the wells are so circumstanced that they run risk of contamination by reason of drains, privies, cesspools, or middens, or by deposit of manure—

whether derived from human excreta or not in or on the ground in the neighbourhood of the wells."

Rain-water is soft and well aërated, but its purity and fitness for drinking or even for washing depend upon the purity of the atmosphere through which it falls. Near the coast it often contains traces of chlorides and sulphates. In inland districts there is a marked increase in the sulphuric acid, ammonia, and organic matter, owing to putrefactive processes and the combustion of coal. Near towns rain may become acid in reaction, from excess of sulphurous and sulphuric acids, and is liable to carry down considerable quantities of tarry and carbonaceous matter from the smoky air. It acquires from the air not only oxygen, nitrogen, carbonic acid and ammonia, with a minute amount of nitric acid, but also any organic or other impurities that may be present in the air. Ammonia is found in largest proportion during the early part of a shower. A litre of rain contains about 25 c.c. of gases, namely, 8 c.c. of oxygen, 16·5 c.c. of nitrogen, and 0·5 c.c. of carbonic acid. Dew and snow-water have practically the same characters as rain-water, except that the dissolved gases are in less amount in snow-water. The average of 20 years, less one-third, gives the amount of rain in the driest year, and plus one-third the amount in the wettest year. (*Hawksley.*)

Springs and wells.—The portion of the rainfall that sinks into the ground becomes heavily charged with carbonic acid from the air in the interstices of the soil, and aided by this and by the increasing pressure it dissolves out lime and various mineral salts from the strata through which it passes. From the superficial strata it also receives organic matter, but the tendency of filtration through the soil is to remove this, or (in the superficial layers, where oxygen

is present) oxidise it with formation of nitrates. The nature and amount of the mineral matters in solution are determined by the soluble constituents of the various strata through which the water has passed, and the organic impurities are regulated by the facilities for pollution in the superficial soil and the completeness of purification by filtration. Hence the water in shallow wells, especially if situated near dwellings or manured lands, is liable to contain much organic matter washed from the soil, with or without partial oxidation into nitrates or nitrites; and also chlorides, which usually accompany organic impurities of sewage origin. In peaty districts the water acquires a brown tint due to vegetable matter.

According to the depth of the strata from which it is derived, the water may be warm, or of the mean temperature of the locality, or varying in temperature according to the season.

River-water is derived partly from springs, but chiefly from that portion of the rainfall which runs off the surface. Hence it contains a variety of mineral salts in solution, though in less amount than in spring or well water.

All streams are inevitably polluted to a certain extent by organic matter. Moorland streams contain peaty matter, sometimes in sufficient quantity to produce diarrhœa. Even in rural districts, drainage from manured land and farmsteads finds its way to the river, and in times of heavy rain much impurity of animal and vegetable origin is washed into the watercourses. Such slight degrees of pollution are not regarded as rendering water unfit for drinking purposes, especially after filtration. Some of the organic matter is oxidised by agitation and aëration, assisted by nitrifying organisms, or removed by aquatic plants, and the bacterial

contents of river water may be much reduced by natural processes. For example, it has been shown by experimental investigation that the movement of river water, and its pressure, exert such an influence. Oxidation, dilution, sedimentation, the bactericidal influence of light, and the antagonism of the fauna and flora of a river, also operate in the same way. When, however, the sewage of hamlets, villages, and towns is poured into the river, the pollution becomes more serious, and the self-purifying agencies are soon overpowered. Even if the sewage added at any one point be insufficient to make a perceptible difference in the whole volume of water, it will contribute to it, and the risk of specific pollution, discernible neither by optical nor chemical tests, must always render such a stream a questionable source of supply. Trade effluents—for example, refuse from dyeworks, paper-mills, and bleachworks—cause even more discoloration and turbidity than sewage proper. From these combined causes the rivers in the manufacturing districts become foul, discoloured, and offensive. Matters are made worse by the refuse from slaughter-houses, solid household refuse, and even contents of privy middens being cast into the river. When the pollution reaches such a degree as this, the purification by oxidation is insignificant. Putrefaction goes on, however, and the suspended matters are slowly deposited in the bed of the stream, so that there is still a tendency to self-purification. The foulness of rivers has rendered it necessary for the towns on their banks to impound pure water which formerly passed into the natural watercourses and helped to dilute the impurities cast into them. Lastly, the flow is in many rivers to a great extent intermittent.

Owing to trade exigencies, volumes of water are in many places impounded, and are only passed into the stream during work hours. In seasons of drought this may for a time almost

entirely arrest the flow of pure water, so that sewage or other impurities that gain access to the stream remain undiluted. This evil is greatest on Saturdays and Sundays, but occurs daily, and continues until such time in the day as the reserved flow reaches the point in question. When water is abstracted from the head of a stream for the supply of a town, it is customary to provide a "compensation reservoir" in which the storm waters are impounded, and whence they can be delivered to supplement the remaining flow in the river in dry weather. As a means of regulating the flow these reservoirs are very valuable, but as for trade purposes the discharge is often made intermittent, the lower part of the stream may suffer from delay in the delivery of the "compensation" water, in addition to the loss of the water permanently abstracted from the channel. An intermittent flow may have some beneficial influence in flushing the bed of the stream, but where there is great impurity any interruption of flow causes increased nuisance by exposure of a foul foreshore.

Mode of supply.—In thinly populated districts water is obtained from streams, springs, or wells, supplemented by storage of rain-water.

The depth to which it is necessary to sink a well depends upon the surface conditions as well as the arrangement of the strata beneath. Even shallow wells may yield good water unless exposed to pollution, as for instance by the proximity of leaking cesspools, ashpits, drains, or even dwellings. Water will usually be found collected as in a basin, above the first impervious stratum of clay, and as the surface of this subterranean reservoir will vary according to season, the well must be deep enough to reach its level in times of drought. Such a well drains a wide area, and is liable to be polluted by any impurity of the soil within a considerable radius of its mouth, and as the supply is at best subsoil water, due regard must be had to the possibility of pollution at comparatively distant points. It should be lined with brick and puddled, and the brick lining should be brought a foot or two above the ground so as to exclude surface washings. If the soil is polluted, or if the

water found is impure or insufficient in quantity, the boring is carried through the first impervious stratum to other water-bearing strata deeper down. Sometimes the water in the deeper strata is under sufficient pressure to make it rise to the surface and overflow, forming an "artesian well" or artificial spring. The flow in dense strata being slow, each well exhausts a considerable area, and the yield of water cannot be greatly increased by multiple borings. Borings in sandstone or limestone give large and constant supplies,

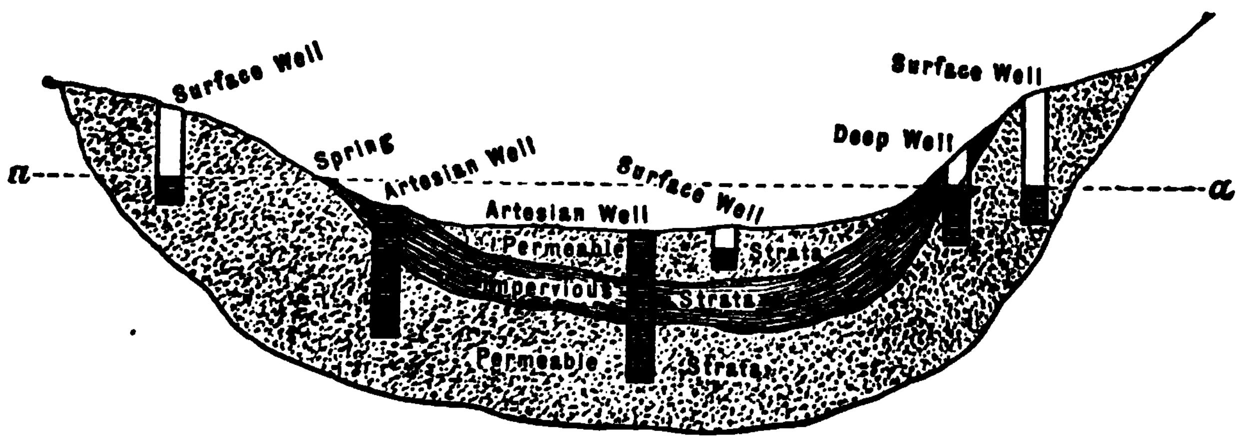

Fig. 4.—Diagrammatic Section across a Valley.
a a, Level of water in deeper permeable strata.

owing to the enormous accumulations of water they contain, but wells in superficial sand or gravel beds, or chalk, often fail in dry seasons (Fig. 4).

Tube wells ("Abyssinian") are convenient for small or temporary supplies. A jointed iron tube is driven into the ground, section by section, the lowest being pointed and perforated at the end. When water is reached, it enters the tube through the perforations and is pumped up if the pressure is insufficient to bring it to the surface. Where the water does not rise to within 25 feet of the surface a deep well pump is necessary. "Abyssinian" tube wells are most suitable for gravel, coarse sands, chalk, and other porous water-bearing strata, and may be driven to any depth up to 150 feet. They are not to

be recommended for clays, marls, and fine sands, and, of course, they cannot penetrate rock.

In the country, and in certain towns where the air is free from smoke, the rain falling upon the roofs is collected and stored in cisterns for domestic use. It may, however, be collected from any other natural or artificial impervious surface. Its softness renders it valuable for washing, especially if the alternative supply is hard, but owing to sooty and other matters acquired from the air and from the roofs themselves, it is seldom obtained in a state of sufficient purity for drinking purposes. It has been estimated that on the average only about two gallons per head *per diem* could be collected in this way.*

If rain is relied upon for more than an auxiliary supply, the collecting surface and storage capacity must be regulated by the minimum annual rainfall and the longest dry season.

Collection and storage.—Water is supplied to towns from reservoirs placed at a sufficient height to allow of its distribution by gravitation through open or closed aqueducts, leading to the street mains and through them to the service-pipes. Pumping stations may be requisite in order to gain this elevation, and if the source of water is of insufficient purity, settling tanks and filter beds may also be required. When the yield is liable to intermission, large storage capacity in the reservoirs becomes necessary. Supplementary service reservoirs, fed by the main reservoirs, are often constructed in elevated parts of the town, partly for convenience of distribution to certain districts, partly in order to supplement the supply during the hours of maximum demand, and so

* The annual yield is found by multiplying the inches of annual rainfall by the square inches of sectional area of the building (not the slant surface of the roof). This gives the cubic inches of water per annum, and multiplied by 0·0036, the number of gallons.

to avoid the necessity of regulating the calibre of the principal aqueduct by the greatest hourly consumption, which is double the average hourly consumption.

If water with a head of H feet flows through L feet of pipe D inches in diameter, the discharge W in cubic feet per minute will be

$$W = 4{\cdot}72 \frac{\sqrt{H \times D^5}}{\sqrt{L}}. \quad \text{Hence } D = {\cdot}538 \sqrt[5]{\frac{L \times W^2}{H}}.$$

The source of supply may be deep wells, springs, lakes, rivers, smaller streams, or artificial adits from gathering grounds. Some of these sources are immediately dependent upon the rainfall for their continuance, so that in planning a water supply it is necessary to take into account the area of the gathering ground, the minimum annual rainfall, the longest rainless period, the proportion of rainfall available for collection, the storage capacity of the reservoirs, and the amount of water required by the district to be served.* Water of the greatest purity is obtained from deep wells, or from barren uplands, where the risks of animal or vegetable pollution are slight.

Reservoirs are constructed either by excavation or embanking, the simplest plan being to carry an embankment across a valley. A lining of concrete or clay puddle may be needed to render them watertight. The embankments, necessarily of great strength, have a core of clay puddle and are protected from disintegration by a covering of grass on the outer side and dressed stone on the inner.

Means are provided of diverting the tributary streams along a by-wash when they become foul in

* In such cases the reservoirs should be large enough to hold at least 150 days' supply, and more in dry localities. If R = mean annual rainfall, E = evaporation (page 24), and A = acreage of gathering ground, then the mean daily yield in gallons is 62 A (R − E). In the driest year the rainfall will be ⅓ less, in the wettest ⅓ more, than the average. (Symons.)

flood times. The reservoir has an overflow weir, and can be emptied for cleansing purposes by means of a pipe, controlled by a sluice, leading from its lowest point. Fish and aquatic plants are found to increase the purity of the water.

From the reservoirs the water passes to the aqueducts by an outlet pipe, which is bent upwards at its commencement so as to take the purest water, free alike from sediment and floating matters. The aqueduct may be an open channel, but usually consists of iron pipes buried two or three feet in the ground as a protection against frost. The pipe aqueduct may be lined with pitch or other anti-corrosive, and being watertight, its course is not necessarily downward at all points. Means of access are provided at short intervals for cleansing purposes, and if its course is undulating, sluices are needed at the lowest points for scouring out *débris*, and air vents at the summit.

Distributing conduits and mains convey the water to all parts of the district, and pass beneath the streets. They are similar in construction to the main aqueducts, and have "scouring valves" at all dead ends in order to wash out sediment. They should be kept as far as possible from the sewers and gas mains.* Hydrants are provided at short intervals for use in case of fire.

Service pipes convey water from the street main to the house, and are controlled by means of stop-cocks. Lead piping is generally used, owing to the many bends and joints needed in distributing water within the house. If, as is sometimes the case, the water is of such quality as to act upon lead, other materials must be employed for domestic supplies.

* There is danger of in-suction if a perforation exists in a descending pipe, and especially at a point of constriction, even if the pipe is constantly full.

Constant and intermittent service.—In almost all provincial towns, and in most parts of London, the water-supply is maintained constantly, save in times of exceptional drought. In some districts, however, the supply is only afforded for a certain number of hours in the day; and it becomes necessary for each household to store a sufficient supply for twenty-four hours, in elevated cisterns. The intermittent system, now becoming obsolete, is attended by many risks and disadvantages, and is only defended on the grounds that it incurs somewhat less waste, and that the substitution of constant service entails better fittings. On the other hand the cisterns, which must be large enough to meet the maximum (not the average) daily consumption, are costly, and are liable to become foul; the water stored in them is stagnant, and absorbs impurities from the air; coal-gas, sewer gases, or liquid filth are liable to be drawn into the mains and service-pipes when empty; and, apart from this, the alternate contact with air and water tends to corrode the pipes and promotes the absorption of lead. In the event of fire, a house or district under the intermittent system is at great disadvantage.

A cistern, if any is needed, should be placed at the top of the house, and fed by a supply-pipe controlled by a ball-cock. It must be large enough to contain at least a day's supply and must not directly supply the water-closet. It may be made of lead, lined with pitch or other protective coating, or of galvanised or Barff iron, or of slate slabs set in cement. It should be effectually covered, but ventilated, and provided with an overflow discharging into the open air away from any source of effluvia. Frequent inspection and cleansing are necessary.

Purification of water may be necessary account of excessive hardness, excess of

constituents, suspended matters, organic matter in solution, or, lastly, on account of liability to specific pollution.

Distillation is the most universally applicable mode, and even sea-water can be utilised in this way. Distilled water has an unpleasant taste, and is said to be indigestible from its want of aëration. This can be remedied by exposure to the air in finely divided currents, as, for instance, by letting it fall from a sieve, or by charging it with CO_2 under pressure.

Boiling removes temporary hardness and destroys microbes, and therefore specific contagia. Some of the organic matter is carried down with the calcium carbonate. Boiled water tastes flat, and, like distilled water, needs aëration. Lime is thrown down more completely if sodium carbonate is added.

Chemical processes are for the most part intended to remove excess of lime. Hard water may be softened, and at the same time deprived of all suspended matter, organic or mineral, by adding about six grains of alum per gallon. Calcium sulphate and a bulky precipitate of aluminium hydrate are formed, and carry down suspended matters. If no calcium carbonate is present, calcium chloride and sodium carbonate must be added previously. Perchloride of iron ($2\frac{1}{2}$ grains per gallon) acts similarly.

Clark's process.—Hard waters may be softened upon the large scale in reservoirs by adding one ounce of quicklime per hundred gallons, for every degree of temporary hardness. The lime and calcium bicarbonate react to form insoluble calcium carbonate, and this carries down with it suspended matters. A similar process may be employed on the domestic scale, using lime or washing-soda, or both.

The Porter-Clark process is a modification of Clark's. Instead of waiting for slow subsidence, which takes ten or twelve hours, the precipitated

calcium carbonate is removed rapidly by filtration through cloth, under pressure.

Filtration aims at straining off suspended matters, and oxidising dissolved organic substances. Mineral salts in solution, such as sodic chloride or calcic sulphate, are at most only partially removed by filtration. As a rule, however, hardness is lessened, together with the nitrites and ammonia. Nitrates are increased.

For domestic filtration a sand filter capable of removing suspended matters and some of the organic impurity may be constructed like a miniature filter-bed, in an ordinary flower-pot, with or without the addition of a layer of animal charcoal (6–12 inches of fine, sharp sand, superimposed on an inch or two of small gravel). Sponge-filters have deservedly fallen into disrepute; they remove suspended matters, but become foul, and harbour organisms. Carbon is the commonest of all filtering media; and animal charcoal is believed to have a far greater purifying effect than vegetable charcoal. Many efficient patterns of filters are made essentially of animal charcoal; others depend upon silicated carbon, manganous carbon, magnetic carbide of iron, or "carferal" (charcoal, iron, and clay). Maignen's "filtre rapide" has no carbon block, but the water is made to pass through a mixture of powdered charcoal and lime (*carbo calcis*), supported upon an asbestos cloth; like other animal charcoal filters, it seems to have the power of removing lead. The medium can be renewed without difficulty. Bischof's spongy-iron filter, besides removing the organic matter, lessens the hardness, and often reduces nitrates to ammonia.

Ordinary domestic filters do not completely remove microbes, and, indeed, some charcoal filters appear to increase the number of bacteria in water passed through them. This is owing to the fact that charcoal may add nitrogen and phosphates to water, which

are both nutritive substances on which bacteria flourish, and may absorb impurities from the air, and thus favour the growth of organisms in its substance. To remove all bacteria, filters of a different class are required, with excessively fine pores through which water can be forced under pressure, without permitting microbes to pass. Pasteur-Chamberland's, composed of porcelain formed by a mixture of kaolin and other clays, is the best example of this kind (*Woodhead, Horrocks*); the Berkefeld filter, somewhat similar, is made of infusorial earth. If much organic pabulum be present in the water, or the filter be used intermittently, or the water forced through it, even filters of this kind are not proof against microbes growing through; and periodic sterilisation by steam or boiling is therefore necessary.*

Filtration upon a large scale is necessary when a public water-supply is turbid or impure. The "filter-beds" constructed for this purpose are essentially shallow reservoirs, one or two feet of water, under-drained by perforated or loosely-jointed pipes, to reach which the water passes downwards through successive layers of fine sand, coarse sand, oyster shells, fine gravel, coarse gravel, and pebbles, the total thickness being several feet. Vents are carried from the deeper layers to above the surface of the water, to allow of the escape of the air displaced by the water as it first descends. From time to time the beds are run dry, for the purpose of aëration; and occasionally they are cleansed by scraping off the sediment and a little of the superficial fine sand, fresh sand being added when necessary. The suspended impurities are strained off by the upper

*A filter (other than Bischof's) should be emptied from time to time to promote aëration, and requires frequent cleansing and occasional renewal of the carbon or other medium. Cleansing may be effected by scrubbing the carbon block, if removable, then running an acid solution of potassium permanganate through it, followed by copious washing with very weak hydrochloric acid, and finally several gallons of water.

portion of the filter, and a certain degree of oxidation of organic matter is effected by the aid of nitrifying organisms. Hardness is diminished somewhat, and iron is removed. It has been shown that filtration through sand removes 95 to 99 per cent. of the microbes present in water (80 per cent. of the bacteria removed were found in the upper inch of sand, and 55 per cent. in the upper quarter inch). If the gelatinous film which forms at the surface of the filter is not disturbed, and if the speed of filtration does not exceed 4 inches per hour, practically all the microbes are arrested. Those in the effluent come from the filter itself, and should not exceed 100 per c.c. (*Koch.*) Frankland holds that the efficiency of sand filtration depends upon (*a*) the storage capacity of the unfiltered water, for purposes of subsidence by sedimentation; (*b*) the thickness of fine sand through which the filtration is carried on; (*c*) rate of filtration; and (*d*) the renewal of the filter bed. The gelatinous film on the surface of the filter is the vital layer where the process of nitrification and arrest of bacteria goes on, and it is there that the filter exerts its chief effect. It may therefore be said that sand filtration depends upon four processes: first, there is subsidence of the grosser particles of impurity in the settling tank; secondly, there is mechanical obstruction to impurities in the interstices of the filter; thirdly, there is oxidation of organic matter in the pores of the filter-bed; and fourthly, micro-organisms in the vital layer on the surface of the filter carry on the process of nitrification. The efficacy of the filtration can only be measured by periodical bacteriological and chemical examinations. The former should include an estimation of the number of B. coli present per c.c.

Other materials may be employed in the construction of filter-beds, such as magnetic carbide of iron covered by a layer of sand to intercept the suspended

impurities. Such a filter-bed must be worked slowly and intermittently, so as to renew the aëration. Spongy iron can be used on the large scale, or "batteries" of Chamberland's filters. At Antwerp "revolving purifiers" are used—cylinders containing small loose pieces of spongy iron, and having many projections from the inner surface. Their long axis, upon which they rotate, is horizontal or inclined, and the surfaces of the iron masses inside are kept constantly bright and clean by mutual friction. Water is passed slowly through the cylinders as they revolve, and is exposed to the action of the constantly fresh iron surfaces. Subsequently sand filtration is used to remove the iron. Metal cylinders containing filtering material (known as "scrubbers"), polarite, sand and polarite mixed, etc., have also been used for filtration of water.

If the source of supply is a river, storm- or flood-water should be excluded. A preliminary purification by subsidence tanks may be beneficial, and floating matters may be excluded by admitting the water from the river through a submerged sluice.

EXAMINATION OF WATER.

Collection of samples.—The amount required depends upon the mode of analysis to be adopted. Half a gallon, or $2\frac{1}{2}$ litres, will suffice for almost all purposes, and this quantity is held by an ordinary stoppered "Winchester Quart." The bottle is rinsed out with a little hydrochloric acid, and then with water until the rinsings are no longer acid. At the time of collection it is again rinsed with sample water, and then filled up to the neck. The stopper should be tied in.

In order to obtain a fair sample, it is well, in the case of rivers or ponds, to plunge the mouth of the bottle under the surface of the water, at a distance

from the margin, so as to exclude scum and *débris*, care being taken not to stir up any sediment. Tap water should be allowed to run for some time before sampling, unless it is desired to ascertain the maximum impurity.

Accompanying the sample should be a more or less full statement of its source. For, in addition to a chemical and bacteriological report of a water, there should also be made *a careful examination of the gathering ground.* The physical configuration of the gathering ground, its subsoil (the occurrence or otherwise of peat), its geology, its rainfall, its relation to the slopes which it drains, the nature of its surface, the course of its feeding streams, and the absence or presence of vegetation and cultivated areas, of roads, of houses, of farms, of human traffic, of cattle and sheep—all these points should be noted, and their influence, direct or indirect, upon the water carefully borne in mind.

When the sample has been duly collected, sealed, and a label affixed bearing the date, time, and conditions of collection and full address, it should be transmitted (preferably in an ice-box) with the least possible delay to the laboratory, in order that the examination may be made immediately.

Physical characters.—Water should be clear and bright, free from turbidity or smell, and have a fresh agreeable taste, without perceptible saline or other accessory character. The colour, as seen by looking down upon a white surface through a column of the water two feet in depth, should be clear, or slightly green, or blue; a yellow or brown tint raises suspicion of organic pollution.

NATURAL WATERS may contain—

In suspension—Particles of animal, vegetable, and mineral origin.

Microbes, and other living organisms, animal and vegetable.

In solution—Gases.
Mineral salts.
Soluble organic matter of animal and vegetable origin.

Suspended matters.—The water should be allowed to stand for a day in a tall glass, and the sediment then examined under the microscope.* Particles of sand have a sharp angular outline. Fragments of chalk and clay are amorphous, but a drop of acid introduced beneath the cover-glass will dissolve chalk, leaving clay unaffected. Shreds of cotton or linen are easily recognised under the microscope, and so are fragments of leaves, woody fibre, and other vegetable tissues, if not so decomposed as to be apparently structureless. Hair, wool, fragments of insects, and even epithelial scales may be found; brown globular bodies attributed to sewage contamination are sometimes seen in polluted water.

For the most part suspended matters can scarcely be deemed injurious; but some of them, cotton fibres for example, may supply important evidence of pollution by household waste, or even sewage.

Living organisms.—Rhizopoda, Infusoria, Hydrozoa, Rotifera, Scolecida, Entomostraca, and Insecta are found in water, together with Fungi, Algæ, Diatomaceæ, and many other organisms. For the most part these are believed to be harmless in themselves, though Infusoria (*e.g. Paramecium, Vorticella*) and Fungi indicate the presence of impurities, and a relatively large number or amount of vegetable or

* One form of sediment tube is shaped like a pipette, the point of which fits accurately into a little glass cup wherein the sediment collects. Finally a long rod is passed down the tube so as to stopper it from the inside at the point. The cup, containing the sediment and about 1 c.c. of water, can then be removed for examination.

animal forms of life indicate the presence of organic pabulum for their sustenance. Among the parasites that are believed to be conveyed by water are certain tapeworms, the Guinea-worm, *Dochmius duodenalis*, *Bilharzia*, and leeches. They may be found in the adult or embryonic form, or as ova.

Bacteria in Water.—In all surface waters bacteria abound, and they are often present in small numbers in deep-well or spring waters. Water bacteria include micrococci, spirilla and bacilli, the last being by far the most common group. They multiply in water with great rapidity. If a sample of ordinary water be allowed to stand, it will be found that in 24 hours there has been enormous multiplication, which continues for three or four days, until there may be hundreds of thousands or perhaps millions of bacteria in a cubic centimetre; then, the pabulum and volume of water remaining the same, there will be a diminution, until in, say, two or three months' time there will be in all probability few or none. In a general way it may be said that foul waters rich in putrescible animal matter show a very rapid increase of bacteria; surface waters, such as river water, show a slow and persistent multiplication of organisms; whereas deep-well waters and spring water show comparatively little increase in contained bacteria. The three chief conditions affecting multiplication of bacteria, with few exceptions, are (*a*) temperature, (*b*) period of time of standing, and (*c*) pabulum in the water.

Number of Bacteria in Water.—Deep-well water generally contains but few bacteria (say 1–10) per c.c. River water varies in its bacterial content according to season (*i.e.* temperature) and according to degree of pollution of the river (*i.e.* organic pabulum). Crookes and Dewar found unfiltered Thames water in June, 1904, contained 883 bacteria

per c.c. (filtered, 20), but in December, 5,875 per c.c. (filtered, 29). In 1903, a year of exceptionally heavy rainfall, and therefore of much surface pollution of the Thames, the number of bacteria in June, when the average would under ordinary circumstances have been low, was 10,337 per c.c. ; in October of the same wet year the number reached 16,671, and in December 27,216. Yet after this water had passed through the filters the number was reduced to 42, 66, and 37 bacteria per c.c. respectively. Prausnitz has shown that waters differ in bacterial content, as would be expected, according to the locality in the river at which examination is made. His investigations were made from the Isar before and after it receives the drainage of Munich, with the following results :—

Above Munich	531	bacteria per c.c.
Near the entrance of principal sewer ..	227,369	,, ,,
Thirteen kilometres below Munich ..	9,111	,, ,,
Twenty-two ,, ,, ..	4,796	,, ,,
Thirty-three ,, ,, ..	2,378	,, ,,

In this country many similar investigations have been made. In 1901 Boyce found in the Severn :

Two miles above Shrewsbury	7,000	bacteria per c.c., including	13	B. coli.
Opposite Shrewsbury ..	13,000	,, ,, ,,	46	,,
One mile and a half lower down	23,000	,, ,, ,,	321	,,
Two miles and a half ,,	19,000	,, ,, ,,	600	,,
Nine miles ,,	13,000	,, ,, ,,	48	,,
Sixteen miles ,,	5,000	,, ,, ,,	36	,,

From these and many similar records it is evident that, in the result, the number of bacteria in river water depends upon a variety of circumstances, amongst which the most important direct conditions are (1) local pollution ; (2) natural purification ; (3) season and rainfall, and (4) sedimentation and filtration. Behind these direct conditions we also know that time, temperature, light, exposure to air, etc., exert more or less influence.

There is no hard and fast rule as to how many

bacteria a potable water should contain, as the kind of bacteria and the relative abundance of each species are more important data than actual numbers. Koch, however, has suggested 100 bacteria per c.c. as a maximum number for a properly filtered water. Macé proposed a standard of 0–50 per c.c. as "very pure," and 50–500 per c.c. as "good water." Estimations of water based only upon counting "colonies" of bacteria in plate cultures are of little value, but other things being equal and constant, a small number of organisms tends to indicate a small degree of organic pollution and conditions unfavourable to the multiplication of bacteria. Broadly, it is true that a water containing a large degree of organic matter, the pabulum of bacteria, will contain a higher number of bacteria than a water containing a low degree, and this, of course, is the scientific reason for quantitative estimations.

Species of bacteria in water.—There are three chief groups of water bacteria, as follows:—

(i.) *Ordinary water bacteria*, including the fluorescent bacilli, liquefying and non-liquefying, many of the common chromogenic organisms, and organisms of air and soil. They are of little importance unless present in large numbers, and they possess no pathogenic power.

(ii.) *Sewage bacteria*, including *B. coli communis* and its allies, the *Proteus* family, *B. enteritidis sporogenes* of Klein, and certain streptococci and staphylococci. The most important member of this group is B. coli. This is a motile, non-spore-bearing bacillus, possessing a limited number of flagella, capable of fermenting glucose and lactose, of curdling milk with the production of acid, of forming indol in broth culture, reducing neutral red broth with the production of a green fluorescence, producing gas-bubbles in nutrient gelatine, forming a more or less brownish growth

on steamed potato, and producing on the surface of gelatine a dry, translucent growth which does not liquefy the medium. The bacilli, under the microscope, appear as cylindrical rods, showing more or less motility, having a few short flagella, and they do not stain by the method of Gram.

The important point is the differential diagnosis of *B. coli*, and the following characters are now chiefly relied upon:—1. The *B. coli* group is non-sporing and non-liquefying. 2. The members of the group rarely stain by Gram's method. 3. They produce acid and gas with both glucose and lactose. 4. They produce acid in milk, and they usually also coagulate it. 5. They produce acid and gas in bile-salt-glucose-broth. 6. They grow well at a temperature of 24° C. Other fairly reliable features are motility, a small number of flagella, a fairly typical growth on potato, and more rapid development on all media than the typhoid bacillus. It is also desirable to remember the characteristics of the three groups of bacilli most readily confused with the coli group. These with their characteristics are as follows:—

(*a*) The *Proteus* group, the members of which are motile, liquefy gelatine, produce gas in glucose and sacrose but not in lactose, curdle and acidulate milk very slowly, and usually produce indol; (*b*) the group including *B. lactis aërogenes*, non-motile bacilli, which do not liquefy gelatine but which curdle and acidulate milk and ferment sugars other than glucose; and (*c*) the *enteritidis* group, containing bacilli which are motile, which only ferment glucose, and which do not liquefy gelatine or curdle milk, which is ultimately rendered alkaline. This group includes *B. enteritidis* of Gaertner, the paracolon and the paratyphoid bacilli.

Streptococci in water usually denote recent and

dangerous pollution of water with sewage matter. They are absent from even large quantities of pure water and from virgin soils.

(iii.) *Pathogenic bacteria* occur in water occasionally. The two chief types are the typhoid bacillus and the cholera bacillus. These diseases and their causal organisms are dealt with subsequently. As a rule pathogenic germs occur in water scantily and intermittently. They gain access at the source or gathering ground, in the course or from drainage and sewers, or, thirdly, in the home of the consumer.

Bacteriological Examination of Water.—Strict cleanliness must be observed in collecting samples for bacterioscopic examination. Only sterilised vessels or flasks must be used (by heating to 150° C for 2-3 hours) and great care must be taken in manipulation at time of collecting the sample in order to avoid the smallest degree of external pollution. The object of bacteriological examination of water is fourfold. (*a*) The enumeration of the bacteria present on a medium incubated at room temperature (18-22° C.); (*b*) Search for B. coli and its identification and enumeration if present; (*c*) Enumeration of bacteria capable of growing at blood-heat (36-38° C.); (*d*) Search for and enumeration of streptococci. Small quantities of the water to be examined (0·1, 0·2 or 0·3 c.c.) are added to tubes of sterile liquefied gelatine, which are then poured into sterilized Petri dishes or flat glass plates. The gelatine solidifies, and the plates are incubated at 20°-22° C. and examined day by day. Soon after the lapse of 24 hours, colonies, arising from original individual bacteria, appear. These are examined by naked eye and microscope, and subcultures made in test-tubes containing suitable media—gelatine, broth, milk, agar, potato, blood serum, etc. Thus the number of organisms per c.c. can be estimated, and the species isolated and separately studied in "pure culture" under favourable conditions. Agar plates should also be made for incubation at blood heat. Slide preparations, stained or unstained, can be made for microscopical examination. This is the ordinary plate method of examination of water, and should as a rule be followed.

Some bacteriologists prefer to take a sterilised Berkefeld filter and pump or aspirate through it 1,000-2,000 c.c. of the

water under examination, and with a sterilised brush transfer the particulate matter which has collected on the caudle of the filter into 10 c.c. of water or broth. This is now a concentration or emulsion of the organismal content of the water, and may be plated out as above or examined for special organisms (B. enteritidis sporogenes, B. coli, B. typhosus, streptococci, or sewage organisms).

Other bacteriologists, aiming only at the detection of organisms of intestinal type, or B. coli or the spores of B. enteritidis sporogenes, adopt the method of (*a*) inoculating bile-salt-broth cultures with 1-20 c.c. of the water to be examined; after 24 hours the tube containing the smallest quantity of water showing acid and gas is selected for further examination. If, after 48 hours, there is no such reaction, no further examination is made. (*b*) A small quantity of the culture is added to 10 c.c. sterilised water, and a loopful of the mixture spread over a plate of bile-salt-lactose-peptone agar, containing neutral red, and made faintly alkaline to litmus. Any growth is subcultured for diagnostic purposes.

Gases in water.—A litre of water can dissolve 25 c.c. of oxygen, 46 c.c. of nitrogen, and 1,000 c.c. of carbonic acid at ordinary temperature and pressure. These gases are usually present in natural waters, but the proportions are very variable, being largely dependent upon the source of the water, the degree of pollution and of exposure to air, and also upon vegetable growth; chalk and limestone waters contain excess of carbonic acid. The gases in a pure water often contain 30 per cent. of their volume of oxygen. They may be extracted for the purpose of quantitative analysis by means of a Sprengel pump, or by boiling the water for an hour, and collected over a mercurial trough. Potash will then absorb the carbonic acid, and potassium pyrogallate or sodium hyposulphite will remove the oxygen, leaving a residue of nitrogen alone.

For the determination of oxygen alone, Thresh adds measured quantities of sulphuric acid, sodic nitrite, and potassic iodide, to a measured volume of water (about 250 c.c.), in a vessel which must be full to the stopper, so as to exclude atmospheric oxygen. The nitrous acid acts as a "carrier"

until all the dissolved oxygen is exhausted, liberating a proportionate amount of iodine. The water is then run into a bottle, through which a current of coal gas is being passed, and standard hyposulphite is added from a burette until the yellow colour due to iodine disappears, the final point being accurately determined by adding a little starch, which gives a blue colour as long as any trace of free iodine remains. The hyposulphite solution is of such strength (7·75 grammes per litre) that 1 c.c. corresponds to ¼ mgr. of oxygen. A correction is required for the oxygen contained in the reagents used, a blank test being made for the purpose. The amount of dissolved oxygen per litre of water is then readily calculated.

Sulphuretted hydrogen or marsh gas may be found, the former due to mineral sulphides such as pyrites, or to decomposition of sulphates by organic matter, the latter to fermentation of vegetable matter in stagnant pools, or to pollution by coal-gas. Traces of ammonia are usually present.

Well aërated waters are bright, lustrous, and agreeable to the palate. This is especially the case with water from wells or springs, of medium depth, in calcium carbonate formations—the low temperature and greater pressure combining to increase the charge of carbonic acid. The absence of dissolved gases in distilled water renders it flat, dull, and unpleasant to taste.

Mineral salts are derived from the strata with which the water has been in contact. They may include chlorides, sulphates, carbonates, silicates, nitrates, nitrites, and phosphates, the bases being lime, magnesia, soda, potash, alumina, or iron, and more rarely lead, zinc, copper, manganese, or arsenic.

The proportion of salts present ranges from practically *nil* in rain-water, or pure moorland water, to 300, or more, parts per 100,000 in "mineral" waters or brackish water from the coast. In water for drinking it should not exceed 40 parts per 100,000, and a good water will not contain more than 10 parts. An excess of mineral salts in general leads to digestive

disturbances, in the form of dyspepsia, diarrhœa, or constipation ; but this effect is largely dependent upon the nature of the salts present.

Chlorides, estimated as chlorine, may reach the proportion of 10 parts per 100,000 in organically pure water from the New Red Sandstone, Greensand, and other saliferous formations. Brackish water and sea water contain excess of chlorine. In general, however, good waters contain not more than about 2 or 3 parts per 100,000, and rain-water and peaty waters little or none. Water from surfaces, shallow wells, or other sources open to contamination should be regarded with suspicion if it contains more than 10 parts of chlorine, especially if there is also excess of organic matter or oxidised nitrogen, all these being significant of sewage or animal pollution.

TESTS.—I. *Qualitative.*—A solution of silver nitrate gives a turbidity with about 6 parts, and a precipitate with about 15 parts per 100,000.

II.—*Quantitative.*—A standard solution of silver nitrate is employed, containing 4·788 grms. per litre, so that each c.c. corresponds to 1 mgr. of chlorine, according to the equation $AgNO_3 + NaCl = NaNO_3 + AgCl$. A hundred c.c. of sample water are taken in a white porcelain dish, a few drops of a solution of potassium chromate are added as an "indicator," and the silver solution is then dropped in from a burette, with constant stirring, until a faint permanent red tinge appears, showing that the chlorine is exhausted, and silver *chromate* is beginning to be formed in place of *chloride*. If the 100 c.c. of sample water take x c.c. of silver solution before the red tint appears, there are x mgr. of chlorine in the 100 c.c., and, therefore, $x \times 10$ mgrs. per litre.*

Sulphates are usually estimated as sulphuric anhydride, SO_3. The most important are calcium and magnesium sulphate, which are liable to cause dyspepsia and diarrhœa in persons unaccustomed to the use

* 1 mgr. per litre = 0·1 part per 100,000, and 1 grain per gallon = 1 part per 70,000. Hence x grains per gallon = $\frac{100}{7} x$ mgrs. per litre, and y mgrs. per litre = $\frac{7}{100} y$ grs. per gallon.

of water containing these salts. Hence limestone and dolomite waters, which may hold 5 to 20 parts per 100,000 of calcium sulphate, are less wholesome than chalk water, which contains none. Dolomite water differs from limestone water in containing magnesium sulphate, but less calcium sulphate. Some waters contain sodium sulphate. The acidity of certain peaty moorland waters that act upon lead has been attributed to the formation of acid sulphates by the oxidation of sulphides (pyrites) or of sulphurous acid absorbed from smoky air.

TESTS.—I. *Qualitative.*—A solution of barium chloride with a few drops of hydrochloric acid will give a white precipitate.

II.—*Quantitative.*—200 c.c. of sample water are boiled, treated with a little hydrochloric acid, and slight excess of barium chloride solution, and then boiled again and filtered. The precipitate collected on the filter is washed, ignited, and weighed as barium sulphate, $BaSO_4$. Given the weight of $BaSO_4$ from 200 c.c., the corresponding proportion of SO_3 per litre will be readily calculated.

Carbonates. — Soluble calcium bicarbonate, $CaH_2(CO_3)_2$, is found in almost all well and spring-waters. It occurs in excess in chalk, limestone, and dolomite water, but it is wanting in rain and peaty water. It is precipitated by boiling, in the form of normal calcium carbonate, $CaCO_3$. Magnesium bicarbonate, $MgH_2(CO_3)_2$, found in dolomite water, behaves similarly, but partially redissolves on cooling. Sodium carbonate is occasionally found in natural waters, and may give them an alkaline reaction. Free carbonic acid exists in all waters, and if in excess renders them sparkling and palatable. Apart from this, the importance of the carbonates in water depends entirely upon the bases they contain. The determination of temporary hardness will show the amount of calcium and magnesium carbonates.

Silicates of soda or alumina are occasionally found in water.

TEST.—Half a litre of sample water is evaporated to dryness; the residue is acted upon by strong hydrochloric acid, and washed with boiling distilled water; then it is once more dried, ignited, treated with acid, and washed with boiling water. The final residue is silica, and may be weighed as such after drying.

Nitrates and nitrites, like chlorides, are harmless in themselves, but if found in a water exposed to risk of pollution may suffice to condemn it for use. Nitrates may be found in pure water from deep wells in the chalk, but as a rule they are due to oxidation of nitrogenous organic matter of animal origin. Even if accompanied by only a small proportion of organic matter, nitrates in water from a source open to suspicion must be regarded as oxidised filth, which may at any time be followed by unoxidised filth.

Frankland emphasised this view by recording all the inorganic nitrogen present, whether in the form of nitrates or nitrites, or ammonia, as due to *previous sewage contamination*, irrespective of its probable origin, recent or remote. He makes a deduction, however, of 0·032 part per 100,000, as the average amount of nitrogen in the rain-water which must have been the ultimate source of supply. Average London sewage is estimated to contain about 10 parts of nitrogen in 100,000 of sewage, so that 1 part of nitrogen represents "previous sewage contamination" to the extent of 10,000 parts.

An example will make the mode of calculation clear. A sample of water is found to contain 3·1322 parts of oxidised nitrogen (*i.e.* nitrogen as nitrites and nitrates) per 100,000 parts of the water; and also 0·0034 part of ammonia, which is obviously equivalent to 0·0028 part nitrogen. The "inorganic nitrogen" is therefore 3·1322 + 0·0028, or 3·1350 parts per 100,000. From this must be deducted 0·032, as a correction

for the nitrogen in average rain-water, leaving 3·1030 inorganic nitrogen, and this multiplied by 10,000 gives 31,030 (per 100,000) of "previous sewage contamination." In other words, if 31,030 parts of average London sewage had been diluted with 68,970 parts of average rain-water, and all the nitrogen then converted into nitrates, nitrites, or ammonia, the result would be a water of the composition of the sample, so far as the proportion of inorganic nitrogen is concerned.

The process of nitrification, by which nitrogenous organic matter in water or in the soil is oxidised, with formation of nitrates, is due in great measure to the action of microbes. Under other conditions, which are not clearly understood, nitrates may be reduced by microbes or by contact with oxidisable matter, yielding nitrogen or even ammonia.

Nitrites, as a rule, indicate more recent and therefore more dangerous pollution than can be inferred from the presence of nitrates. They readily pass into nitrates.

A variety of standard terms has been proposed for the quantitative statements of nitrates and nitrites. The expression "oxidised nitrogen" is adopted here, and is precisely equivalent to "nitrogen as nitrates and nitrites" and to "nitric nitrogen." "Previous sewage contamination" has already been explained. Wanklyn gives his results in terms of "nitric acid," HNO_3.

Water from springs and deep wells contains upon an average about 5 parts of oxidised nitrogen per million, shallow-well waters from 2 to 200 parts.

TESTS FOR OXIDISED NITROGEN.*

I. QUALITATIVE.

a. Diphenylamine test.—A 2 per cent. solution of diphenylamine in strong sulphuric acid is spread out in a thin layer upon a white porcelain plate. A drop of the sample water is allowed to fall in the centre, and any trace of oxidised nitrogen is revealed in a few seconds by a blue tint throughout, or at the line of contact.

* That is, for nitrates or nitrites indifferently.

β. *Horsley's test.*—2 c.c. of pure sulphuric acid are added to 1 c.c. of the water, and then a drop of pyrogallic acid solution. A pink or blue tint appears, changing to brown; it disappears momentarily upon shaking, but soon returns.

γ. *Brucine test.*—A drop of pure sulphuric acid and a crystal of brucine added to the dry residue of 2 c.c. (or more) of the water will give a pink or yellow tint even with minute traces of oxidised nitrogen.

II.—Quantitative.

δ. *Aluminium process.*—2 grammes of sodium are dissolved in 100 c.c. distilled water so as to obtain a pure solution of caustic soda free from nitrates; 100 c.c. of sample water are added and a piece of aluminium foil. In the course of a few hours all the oxidised nitrogen is converted into ammonia, which is distilled off and Nesslerised. Each mgr. of ammonia, after deducting the free ammonia originally present in the sample, corresponds to 0·82 mgr. of oxidised nitrogen in the 100 c.c. of sample.

ε. *Zinc-copper process.*—Zinc foil is coated with copper by exposure to a solution of copper sulphate until it becomes black. It is then put into a bottle with 250 c.c. of the sample water and 0·5 grm. oxalic acid, and left for twenty-four hours. As in the aluminium process, all the oxidised nitrogen is converted into ammonia and measured as such by Nesslerising.

All the preceding tests are for nitrates and nitrites alike. The following apply to nitrites only:—

1. Ilosvay's solution, containing sulphanilic and acetic acids and napthylamine, is an extremely delicate test. A few drops added to water give a rose tint if any trace of nitrate is present.

2. One drop each of phenol and sulphanilic acid solution, and then ammonia, will give a yellow colour.

3. The addition of starch solution, potassium iodide solution, and dilute sulphuric acid causes a blue tint, due to liberation of iodine by nitrous acid and consequent formation of iodide of starch.

4. Meta-phenylene-diamine solution with dilute sulphuric acid (1 c.c. of each to 100 c.c. of water) will give an orange-red colour after standing a few minutes. (*Griess.*)

Phosphates are not of common occurrence except in minute traces. They are, for the most part, indicative of remote animal pollution, but their presence need not condemn a water if other indications are satisfactory.

Test.—The water is concentrated to $\frac{1}{50}$th, 250 c.c. being boiled down to 5 c.c. Nitric acid is added, and then solution of ammonium molybdate. If phosphates are present, a yellow colour will appear, and, on standing, a precipitate of ammonium phospho-molybdate.

Sulphides are said to result from the reduction of sulphates by *Beggiatoa*, and perhaps from contact with iron pyrites. Carbonic acid liberates sulphuretted hydrogen from sulphides. They are readily detected by smell, and by the following:—

Tests.—A solution of lead acetate (or, still better, a solution of lead hydrate in caustic soda) will give a black precipitate in presence of sulphides.

A solution of sodium nitro-prusside will give a purple colour with sulphides, but not with free sulphuretted hydrogen. It is therefore safer first to add caustic alkali.

Lime is the most important of the mineral constituents of drinking water. It occurs mainly as bicarbonate and sulphate; a good water should not, as a rule, contain more than 20 parts per 100,000 of the former, or 5 of the latter. In excess it causes constipation when used for drinking, and is wasteful for washing purposes, since it renders the water extremely hard unless previously boiled. On the other hand, absence of lime salts is held to be disadvantageous, because lime is required in the system, and also for the more practical reason that soft waters are, as a rule, less palatable than those of moderate hardness, and often dissolve lead from household service pipes. Horses are said to become rough in the coat if supplied with very hard water. Calcium sulphate is injurious (as already stated), and

affects lead. Nitrates, chlorides, or excess of carbonic acid have been found to increase the corrosion, while silicates and many other substances exert some protective action.

The acid reaction and consequent intense plumbo-solvent effect of certain moorland waters has been attributed to acid sulphates (due to the oxidation of iron pyrites $FeS_2 + H_2O + 7O = FeSO_4 + H_2SO_4$), to sulphurous or other acid in rain, or to the indefinite acid compounds found in soil, and sometimes termed humic and ulmic acid. In some cases it is caused by excess of carbonic acid; but in the main the acidity is that of peat, due, according to Houston, to acid producing bacteria in the peat. He has shown that a mixture of micro-organisms obtained from peat, when introduced into a sterile decoction made solely from peat, not uncommonly renders the peat decoction acid and plumbo-solvent in character. Further, Houston has isolated two non-motile, non-liquefying bacteria from peat soil which possess separately the properties as regards acidity and plumbo-solvency observed in the mixture of peat microbes. Acidity in water is more marked in the first flow when rain follows drought, owing no doubt to the washing out of the acid accumulated in the peat; and least marked in dry weather, when the contribution from springs is relatively largest. Where peat is abundant, and springs are relatively few and small, acidity and plumbo-solvent ability may be anticipated. But in the absence of carbonate of lime, the power of acquiring lead is shared in considerable degree by many neutral and even slightly alkaline moorland waters, including those in which the acid peat washings have been neutralised by admixture with spring water. Tidy and Odling attributed the lead-dissolving power to the absence of silica, and brought forward evidence to show that this inverse relation holds good in a number of

water supplies. There are, however, many exceptions. Even distilled water, or solution of sodium carbonate in distilled water, will attack lead.

In 1887 Sinclair White called attention to the prevalence of plumbism among the consumers of the high-level water at Sheffield, and disastrous consequences have resulted in other Yorkshire towns from the distribution of plumbo-solvent water through lead pipes.

Various remedial measures have been tried. One plan is to expose the water to fragments of limestone, and conduits have been lined with the same material, but it soon becomes inert, owing to incrustation, and frequent renewal of the surface is necessary. Measured quantities of lime have also been added (2 to 3 grs. to the gallon). A more effective method is to add powdered chalk or whitening ($1\frac{1}{2}$ grs. to the gallon), while in some instances carbonate of soda is used (500 gallons of soda solution, 1 lb. to the gallon, are added to one million gallons of acid water). In some towns reliance is placed upon filtration through calcareous sand, which, however, becomes exhausted in time and needs renewal. In pursuance of Tidy's hypothesis, the water has been charged with traces of silica by filtration through powdered granite or flint. It is at least possible that the mischief is not always due to the same cause, and that no one line of treatment is suitable in all cases. Houston recommends ordinary sand-filtration, with the addition of some neutralising material to the filter (*e.g.*, a thin coating of lime on the surface of the sand with limestone underneath the sand) and the subsequent addition of a *trace* of sodium carbonate to the neutral filtered water.

Many waters, fortunately, are sufficiently protected by the salts they contain. Calcium sulphate is less protective than the carbonate, and magnesium

less than calcium salts. A crust is formed upon the interior of lead pipes, composed of carbonate and sulphate of lead, lime, and magnesia (or such of them as are present in the water), and chloride of lead. Carbonate of lead is difficult of solution except in water charged with excess of carbonic acid under pressure. Pipes which are new, which are bent against the grain, or which are alternately full and empty, are more attacked than others. The maximum amount of lead is found in water that has stood for some time in the pipes, over-night for example. Lead is now chemically purer than was usual in former years, owing to the profitable removal of silver and other metals with which it is found associated, and it would appear that the purer lead is more readily acted upon by water.

Many substitutes for ordinary lead pipes are now available, and where there is any tendency to solvent action one or other of these should be adopted. Compound pipes have long been in use, the interior of which is block-tin and the exterior lead; the two metals are solidly united throughout, and the pipe can be bent without fracturing the tin. A less reliable protective lining to lead pipes may be found in tar or bitumen. Iron pipes are more satisfactory in every respect, except their rigidity, which renders them difficult to adapt to the bends and turns that are needed in houses. Plain iron pipes may be employed, with some risk of trouble from rusting. Tin-lined, glass-lined, or galvanised iron pipes are often used, and among other protective coatings may be mentioned Angus Smith's varnish and collodion. Theoretically, the rustless Barff iron offers the greatest advantages for this purpose; iron pipes of ordinary construction are exposed while hot to superheated steam, and thereby acquire a thin coating of magnetic oxide, Fe_3O_4, which renders them free from liability to rust as long as the coating is unbroken. Unfortu-

nately the film is easily dislodged in the process of fitting. If it is not possible to change the supply of water, or to prevent it by chemical means from acting upon lead, or to keep it from coming into contact with lead, recourse must be had to palliative measures. The water must always be run off for a few minutes in the morning, and again before drawing it for drinking purposes. All that is used for drinking or for cooking should be filtered through some medium containing animal charcoal. Such filters possess the power of removing lead from solution, owing probably to the phosphates which they contain forming an insoluble lead salt.

No water should be used for drinking that contains any trace of lead, for however minute, its presence indicates danger; moreover, the sample may not represent either the seasonal or daily maximum.

Among the symptoms caused by lead-poisoning are anæmia, depression, dyspepsia, constipation, colic, and paralysis of the extensor muscles of the hand, leading to wrist-drop. A characteristic blue line appears along the edges of the gums, due to the formation of sulphide of lead in the tissue. Optic neuritis may be found. It has been observed that abortion is common in districts where lead-poisoning prevails, and sometimes to such a degree as materially to lower the birth-rate. The relation between lead-poisoning and gout and kidney disease is referred to elsewhere.

TESTS.*—I. *Qualitative.*—(*a*) H_2S gives a brown tint if a trace of lead is present, and a black precipitate if much; neither is affected by acid. (*b*) A solution of potassium bichromate (1 gr. per oz.) dropped into a tall glass of water, falls slowly, causing an opaque yellow cloud if there is any lead in solution.

II. *Quantitative.*—A standard solution containing 0·1 mgr.

* The sample should be the first pint, *or less*, drawn from the pipe after standing for an hour or other stated period if it is to measure the maximum impurity.

of lead in 1 c.c. is made by dissolving 0·1831 grm. of crystallised lead acetate in a litre of distilled water. The procedure is the same as in testing for iron, but the water should be made acid.

Acidity of water and plumbo-solvency should also be tested for. The former may be estimated by using lacmoid as an indicator. The solution is best made by dissolving 0·2 grms. of lacmoid in 100 c.c. of dilute alcohol (10 per cent.). A few drops added to 10 c.c. of the sample of water at once reveals the presence of the smallest trace of acid. The amount of acid may be determined by titrating a definite quantity of the water with a decinormal solution of sodium carbonate (5·3 grms. Na_2CO_3 per litre). Phenol-phthalein may be used as indicator.

Plumbo-solvency may be determined in the following way: 50 c.c. (by volume) of washed lead shot are placed in a burette (¾" × 24"), occupying 18 in. of its length; the sample water is allowed to filter through this lead, and is then collected in successive quantities of 50 c.c., and tested with sulphuretted hydrogen or ammonium sulphide for the presence of lead.

Zinc, copper, and arsenic, although rarely occurring in natural waters, may occasionally gain access by means of trade pollution, or by the solvent action of water (especially water containing organic matter, nitrites, and nitrates) upon the pipes and vessels with which it comes into contact. Any trace of these substances renders a water unfit for drinking purposes.

Tests.—Copper, like lead, strikes a black colour with ammonium sulphide, not discharged by acid. It may be determined quantitatively by a colorimetric process similar to those for iron and lead, the standard solution containing 1 mgr. of copper in each c.c. being made by dissolving 3·93 grms. of crystallised copper sulphate in a litre of distilled water.

Arsenic would be detected in the residue after evaporation, by the Marsh-Berzelius or other test.

Hardness of water is caused by the presence of salts that decompose soap, preventing lathering until sufficient soap is added to exhaust them. The chief of these are lime salts, magnesium salts, and carbonic acid, but iron and alumina have a similar effect. By

boiling the water, the free carbonic acid is driven off, and calcium bicarbonate is reduced to the insoluble carbonate and precipitated; magnesium bicarbonate is precipitated as carbonate in like manner, though it partially re-dissolves on cooling, and most of the iron is also thrown down. After removal of this *temporary* hardness, there remain in solution calcium and magnesium sulphates and chlorides, and a little iron—assuming them to have been originally present. These, with the re-dissolved magnesium carbonate, constitute the *permanent* hardness. Soap consists of alkaline oleates, stearates, and palmitates, which form a viscid solution in water. The phenomena of hardness depend upon the formation of insoluble calcium and magnesium oleates, etc.

Hardness is measured by a standard soap-solution, 1 c.c. of which exactly precipitates 1 mgr. of calcium carbonate. It is found that 1 c.c. suffices to give a lather when shaken with 70 c.c. of distilled water, and anything beyond this is due to the hardness, which is stated in terms of calcium carbonate.

70 c.c. of the water is taken in a bottle of about 250 c.c. capacity, and the soap-solution is added by degrees from a burette, with vigorous shaking after each addition, until a lather completely covers the surface and remains intact for five minutes. The number of c.c. added, deducting 1 c.c. for lathering, will give the hardness in mgrs. of calcium carbonate per 70 c.c., that is, in grains per gallon.* The permanent hardness is measured in exactly the same way, in 70 c.c. of the water, after boiling for half an hour and adding distilled water to make good the loss by evaporation. If more than 16 c.c. of soap-solution are consumed by 70 c.c. of water, it is better to dilute it by adding 70 c.c. of distilled water, in which event a deduction of 2 c.c. must be made instead of 1 c.c. for lathering. A "degree" of hardness upon Clark's scale corresponds to a grain of calcium carbonate per gallon.

The disadvantages attendant upon the use of hard water have already been referred to in speaking of

* Hardness, unlike other analytical data, is still commonly expressed in grains per gallon. The conversion into the standard terms is readily effected (*see* note, page 62), for instance, from grains per gallon to parts per 100,000 by dividing by 0·7.

lime and magnesia in water. Temporary hardness is of less moment, both for dietetic and washing purposes, than permanent hardness; it depends upon the comparatively harmless calcium carbonate, which is removed by boiling. Calcium and magnesium salts have been held responsible for goitre, which in certain districts, notably in India, seems to be limited to magnesian limestone formations. It is, however, by no means always prevalent in magnesian limestone districts, even when the water contains abundance of magnesium salts; nor is it always absent from districts free from limestone formations. Hence many authorities are inclined to attribute it to iron pyrites and other salts of iron and copper often found in limestone regions; while others consider that the concurrent agency of some organic material, or a specific organism, is necessary. Goitre appears to have been developed, under the use of certain drinking waters, in as few as eight or ten days. Urinary calculi are common in Norfolk and other chalk districts where the water is hard; but the dependence of the calculi upon the hardness of the water is far from being established. A good drinking water should not exceed 4 degrees of permanent, or 20 of total, hardness. It is estimated that each degree of hardness involves a waste of upwards of a pound of soap for every 1,000 gallons used in washing.

Organic matter in solution consists of animal and vegetable matters that have gained access to the water, and of the products of their decomposition. Little is known of its chemical composition, the variety and complexity of the components being so great as to defy analysis.

The presence of organic matter (or rather, of oxidisable matter) may be shown by adding a few drops of a solution of potassium permanganate, which is immediately decolorised; or by slightly acidulating the sample water and boiling it for 20

minutes with a few drops of solution of chloride of gold, which will give, according to the amount of organic matter present, a rose, violet, or olive colour, or a violet or black precipitate.

A rough quantitative estimate is obtained by determining the combustible matter in the "total solid residue." 100 c.c. of sample water are measured into a platinum dish of known weight A. They are then evaporated to dryness over a water bath (after which the drying should be continued in a water oven at 100° C. for an hour more), and the weight B of the dish and its now dry contents is ascertained. B—A is the weight of the total solid residue, that is, of the organic matter and mineral salts. The dish is next heated to dull redness, to burn off the organic matter, and weighed again (C) after cooling. The loss on ignition, that is B—C, will give the amount of organic matter in the volume of water taken.* The proportion of organic matter per litre, or per gallon, is readily calculated from these data. Thus,

100 c.c.	:	1,000 c.c.	::	B – C	:	x
volume taken.		a litre.		mgrs. lost on ignition.		

x being the proportion of organic matter expressed as parts per million, or milligrammes per litre. During ignition the organic matter turns brown, or even black, before disappearing, and if of animal origin it gives off pungent fumes.

This method is not sufficiently exact for most quantitative purposes, and recourse is had to other means, of which the chief are :—

Wanklyn's ammonia process,
Frankland's combustion process, and
Forchammer's oxygen process.

None of these professes to give the total amount of organic matter in water, but each fixes upon some one or more element, compound, or property, which is determined with precision and taken as a measure or index of the total organic matter, to which it is assumed to bear a constant ratio.

Wanklyn's Ammonia Process.—Most nitrogenous organic matter, when heated with permanganate of potash in presence of excess of potash, gives off a certain proportion of its nitrogen in the form of ammonia. Most, if not all, of the injurious organic impurities occurring in water may reasonably be assumed to be nitrogenous, and as they

* This is not strictly accurate, since water of crystallisation is driven off from the saline matters, and some small portion of the salts may be volatilised. Carbonates lose CO_2, nitrates are reduced, and chlorine volatilises.

yield a definite and fairly constant proportion of their nitrogen as ammonia we have a very convenient and delicate means of measuring them. It still remains, of course, in this as in all other indirect processes, to establish empirical standards of purity, in terms of the ammonia index.

Certain standard solutions are required.

A. Standard solution of ammonium chloride, containing 0·01 mgr. of *ammonia* in 1 c.c.

B. *Nessler's solution* is a saturated solution of mercuric iodide in potassium iodide. It gives a yellowish tinge, with the faintest trace of ammonia, and a yellow-brown precipitate (NHg_2I,H_2O) if more is present.

"Nesslerising" is a process by which the free or saline ammonia in a sample of water can be readily determined with great accuracy. Two tall cylindrical, flat-bottomed glasses, marked at 50 c.c., are placed side by side upon a white surface. In one of them are placed 50 c.c. of the sample water, and in the other 50 c.c. of distilled water free from any trace of ammonia. Two c.c. of Nessler solution are added to each glass, and the tint struck by the sample is exactly imitated by adding to the second glass successive measured quantities of the standard ammonia solution (*A*) from a burette, until the right tint is reached. Each c.c. of ammonia solution used corresponds to 0·01 mgr. of ammonia present in the 50 c.c. of the sample, from which data the amount per litre is readily calculated.

C. Alkaline permanganates olution. Eight grms. of potassium permanganate and 200 grms. of solid caustic potash are dissolved in a litre of distilled water.

The analysis is conducted as follows:—

Half a litre of the water to be examined is put into a large flask, connected with a Liebig's condenser by means of a bent glass tube passing through a perforated indiarubber stopper. The flask is heated by a Bunsen's burner, and the first 50 c.c. of distillate are collected and Nesslerised, and the amount of ammonia they contain is recorded. This ammonia is part of the free ammonia contained in the water as such, and it is found by experience that the first 50 c.c. contain three-quarters of the free ammonia. Hence, adding ⅓ to the amount recorded in the first 50 c.c., we get the whole amount contained in the *half litre* of water under analysis, and, doubling this, the mgrs. of free ammonia per *litre*, *i.e.* parts per million.

Thus, if the first 50 c.c. strike a tint with Nessler, which is matched in the second glass by the addition of 1·2 c.c. standard ammonia solution, we must allow ⅓ of 1·2, that is, 0·4, making

a theoretical total of 1·6 c.c. This corresponds to 0·016 mgr. of ammonia in the half litre taken for analysis, or 0·032 part per million. Meanwhile 150 c.c. more are distilled over, to exhaust the free ammonia, but as already explained it is unnecessary to Nesslerise these.

There are then 300 c.c. left in the flask, and to this are now added 50 c.c. of the alkaline permanganate, and the distillation is resumed. The first, second, and third 50 c.c. are collected separately and Nesslerised. Should the third 50 c.c. be found to contain noteworthy quantities of ammonia, a fourth 50 c.c. is distilled over.

The ammonia coming over at this second stage is called *albuminoid ammonia,* being derived from the albuminoid and other nitrogenous organic matter in the water. The second 50 c.c. contain much less than the first, and the third less than the second. Adding together the amount of ammonia found in the three lots, we have the total for the half litre of water; and twice this will give the proportion in parts per million. Thus,

1st 50 = 2·5 c.c. standard ammonia solution.
2nd 50 = 1·0 c.c. " " "
3rd 50 = 0·3 c.c. " " "

Total = 3·8 c.c. = 0·038 mgr. ammonia per half litre.
∴ Albuminoid ammonia = 0·076 part per million.

Note.—Absence of any trace of albuminoid ammonia is suggestive of organic purity, even if free ammonia and chlorides are high. Albuminoid ammonia less than ·05 part per million is consistent with extreme purity; and if free ammonia is absent or scanty, albuminoid ammonia under 0·10 is no evidence of impurity. If, however, there is much free ammonia, 0·05 albuminoid ammonia is suspicious, and 0·10 is strong evidence of pollution; 0·15 or more should condemn a water absolutely.

In good waters the free ammonia usually ranges from 0·00 or 0.01 to 0·03 part per million, and rarely exceeds 0·05.

Combustion processes involve costly and delicate apparatus, and a considerable degree of skill. The following is an outline of Frankland's process :—

To a litre of the water are added 20 c.c. of saturated solution of sulphurous acid, to reduce the oxidised nitrogen and liberate all carbonic acid. The water is evaporated to dryness. The dry residue is mixed with oxide of copper and heated *in vacuo* in a combustion tube for about an hour. The gases evolved are collected over a mercurial trough; they contain all the organic carbon as carbonic acid, and the nitrogen as such.

They are measured volumetrically, and after the absorption of the carbonic acid by caustic potash the residue is read as nitrogen. The nitrogen present in the water as ammonia must be separately determined, and deducted from the total.

The significant points are the absolute and relative amounts of organic carbon and organic nitrogen. The lower the proportion of nitrogen to carbon, and the less the amount of each, the more favourable is the verdict, other things being equal. A low proportion of nitrogen to carbon, 1 to 8, indicates vegetable organic matter; a high proportion such as 1 to 3 is pretty certain proof of animal pollution. A river or surface water should not contain more than 0·2 organic carbon or 0·03 organic nitrogen in 100,000 parts, and spring or well water is open to suspicion if the carbon exceeds 0·1, or the nitrogen 0·03, per 100,000. In forming conclusions, due weight must be given to the other analytic data, especially the determination of chlorides and oxidised nitrogen, and to the other evidence obtainable, such as the position and surroundings of the source of supply, the facilities for pollution, and the depth and geological characters of the strata from which it is derived.

The following table, taken from the Report of the Rivers Pollution Commissioners, gives the average results of a large number of samples upon Frankland's method, stated as parts per 100,000 :—

	Rain-water.	Upland Surface Water.	Deep-Well Water.	Spring Water.
Total Solid Impurity	2·95	9·67	43·78	28·20
Organic Carbon	·070	·322	·061	·056
Organic Nitrogen .. .	·015	·032	·018	·013
Ammonia	·029	·002	·012	·001
Nitrogen as Nitrates and Nitrites	·003	·009	·495	·383
Total Combined Nitrogen ..	·042	·042	·522	·396
Chlorine	0·82	1·13	5·11	2·49
Hardness :—				
Temporary	0·4	1·5	15·8	11·0
Permanent	0·5	4·3	9·2	7·5
Total	0·9	5·8	25·0	18·5
Number of Samples Analysed	39	195	157	198

Kjeldahl's process, applied by Blair to water analysis, is based upon the conversion of the nitrogen of organic substances into ammonium sulphate if charred by heating with strong

sulphuric acid. 250 c.c. of water are distilled down to 50, with addition of sodium carbonate if acid; the first 100 c.c. of distillate contains all the free ammonia. Then 10 c.c. of pure sulphuric acid and a little arsenious acid are added, and the distillation is continued. Presently the acid begins to fume, and becomes darkened by the charring of organic matter. The heat is continued for two hours after this, or until the colour disappears again. After cooling, a slight excess of pure solution of soda is added: and the ammonia thus liberated is distilled over, and measured as in Nessler's process.

This method, like Wanklyn's, gives us a record of the "free ammonia" and "organic ammonia" at two stages; but the yield of the latter is more constant and more complete than that obtained with alkaline permanganate. The results are converted into terms of "organic nitrogen" by multiplying by 0·824. Blair finds, by this process, less than 0·06 part of organic nitrogen per million in very pure water, and 0·06 to 0·12 in ordinary drinking water; he regards as suspicious any water containing more than this, unless peaty, and condemns any over 0·32.

Oxygen process.—There are many modifications of the Forchammer method, of which Tidy's is the best known. For the sake of uniformity the metric system is substituted for "septems" in the following description:—

The standard solutions required are—

A. Potassium permanganate, 0·395 grm. in a litre of distilled water. Every 10 c.c. yields 1 mgr. of oxygen to oxidisable matter.

B. Sodium hyposulphite, 1 grm. per litre.

C. Potassium iodide, 1 part in 10 of water.

D. Starch, 1 part boiled with 20 parts of water, and filtered.

E. Sulphuric acid, 1 part to 3 parts of water.

The object is to determine the amount of oxygen absorbed in 1 hour and 3 hours respectively. As the hyposulphite solution is liable to change, it is necessary to perform a blank test with distilled water every time.

Four flasks are employed, two of which contain 250 c.c. of sample water, while the other two contain 250 c.c. of distilled water for the control experiments. To each flask are added 10 c.c. of permanganate solution (A), and 10 c.c. of dilute sulphuric acid (E). If the water is very bad, the pink colour due to the permanganate may soon entirely disappear, and in this event a second and even a third 10 c.c. of permanganate

must be added, in order always to have a pink tinge throughout the experiment. At the end of an hour one of the samples and one of the control flasks are tested to ascertain how much undecomposed permanganate remains to be deducted from the total used. For this purpose 2 c.c. of iodide solution (C) are added, and the remaining permanganate immediately acts upon it, liberating a proportionate amount of free iodine. The iodine is measured with precision by dropping in the standard hyposulphite solution until no more free iodine remains, the exact point of disappearance of the last trace of iodine being ascertained by adding 2 c.c. of starch solution (D) near the end of the process, and noting the disappearance of the blue iodide of starch.

In the blank test the 10 c.c. of permanganate should remain unaltered at the end of the hour, so that if x c.c. of hyposulphite are used, these x c.c. correspond to 10 c.c. of the permanganate solution, that is, to 1 mgr. of oxygen. If, therefore, the sample flask, which has, of course, lost some of its permanganate, takes only y c.c. of hyposulphite, it is clear that the oxygen consumed by oxidisable matter must have been $\frac{x-y}{x}$ mgr. If a second 10 c.c. of permanganate had been employed, the formula would obviously have become $\frac{2x-y}{x}$ mgr.

As a quarter of a litre of the sample was taken for each analysis, four times this result will give the "oxygen consumed" in milligrammes per litre—that is, in parts per million.

The determination of oxygen consumed in three hours is conducted in exactly the same way, at the end of that time.

Interpretation of results of the oxygen process.—Not only organic matter, but also nitrites, ferrous salts, or sulphuretted hydrogen, will reduce permanganates, and these latter, if present, must be removed or allowed for. No distinction is made between nitrogenous and non-nitrogenous organic matter. In London waters the organic matter is said to be about eight times the "oxygen consumed." It seems that putrescent matters, notably urine and other animal matter, are readily oxidised by permanganate, so that while the three hours' experiment gives information as to the total amount of organic matter, the one-hour reaction is important as indicating the proportion of putrescent and, therefore, presumably dangerous impurities. Sometimes four hours are

allowed instead of three, and a quarter or half an hour instead of one hour. Peaty waters consume much oxygen.

As in all other modes of estimating the organic matter in water, the results of the oxygen process must be considered together with the other analytic data and the source of the water. In a general way, Tidy classifies waters as of great organic purity if the oxygen consumed does not exceed 0·5 part per million, of medium purity if not exceeding 1·5 part, of doubtful purity up to 2·0 parts, and as impure if the oxygen consumed exceeds 2·0 parts per million. Upland surface waters, however (the organic matters being less likely to be harmful), are judged by a more lenient standard, the degrees of which are double those given above, namely, 1·0, 3·0, and 4·0, in place of 0·5, 1·5, and 2·0.

Blair's oxygen process at 100° C. gives very satisfactory results. The reagents are similar to Tidy's, but the following differ in strength:—

Potassium permanganate, 1·975 gramme per litre, so that 10 c.c. yield 5 mgrs. oxygen.
Sodium hyposulphite, 3·875 grammes per litre.
Sulphuric acid, 100 c.c. to 900 c.c. distilled water.

Half a litre of water is taken for analysis, and after the addition of 10 c.c. of permanganate and 10 c.c. of acid, is boiled gently for two hours, further charges of permanganate being added if necessary. After cooling, the procedure is the same as in Tidy's process. Iodide is added, and the iodine set free by the unconsumed permanganate is measured by hyposulphite solution with the aid of starch.

The method of calculation also is substantially the same. Since the 10 c.c. of permanganate yields 5 mgr. of oxygen instead of 1 mgr., the formula becomes $5 \times \frac{x - y}{x}$, or if n charges of permanganate have been added, $5 \times \frac{x \times n - y}{x}$

This gives the mgrs. of oxygen absorbed per half litre, and doubling the result we have mgrs. per litre, or parts per million. Blair's process has obvious advantages over Tidy's, since the conditons as to temperature are constant, and the oxidation of organic matter practically complete. The empirical standards of purity necessarily range higher. Exceptionally pure waters take less than 2 parts per million, waters of medium purity 2 to 4 parts, and suspicious waters 4 to 6 parts. Even a peaty water should not be recommended if it takes much more than 6 parts.

Interpretation of the results of water examination.—From what has been said, it will be seen that there are various methods of water analysis or examination by which we may obtain a knowledge of a water sufficient to guide us as to its suitability for drinking purposes. In the past too much emphasis has been given to the results of chemical analysis and too little to the facts obtained by bacterioscopic and microscopic examination, and by inspection of the gathering ground. It cannot be too clearly stated that *all* the facts obtainable respecting a water are necessary to a reliable conclusion. Nothing is more likely to lead to an incorrect opinion than reliance upon isolated findings in respect of a water, whether bacteriological or chemical. The two must be taken together and in conjunction with a careful inspection of the sources, and even then the matter must be judged broadly, and the "life history" of the water, if such a term is permissible, taken into consideration.

The chief interpretations of chemical analysis have been already referred to in the text, the importance of gases, mineral salts, and soluble organic matter having been dealt with. It is therefore unnecessary to recapitulate. Here it is only necessary to add that these general rules are subject to modification according to the history and surroundings of the water. Vegetable is much less dangerous than animal contamination, and may often be recognised by the slowness with which the albuminoid ammonia comes over,* by the absence or small amount of chlorides and of free ammonia, and by microscopic examination of the sediment or knowledge of the source of the supply. Animal pollution is indicated if the albuminoid ammonia comes over rapidly, or if the chlorides or oxidised nitrogen are abundant. Pollution by absorption of effluvia, or by the

* The second 50 c.c. containing little less than the first, and the third than the second.

presence of putrefying masses in the water, would, however, be unaccompanied by any excess of chlorides. It is important to take into consideration also the character of unpolluted water in the same district or geological field, since chlorides, oxidised nitrogen, and even a certain amount of free and albuminoid ammonia, may be found in waters that are free from recent and therefore dangerous pollution. It is quite possible, too, for an organically pure water to be unfit for use on account of its mineral constituents. Water from a shallow well, open to suspicion of pollution, should be condemned if the chlorides and oxidised nitrogen are high, even if albuminoid ammonia be scanty. A water that is pure at the time of sampling may still be liable to intermittent contamination. It must be remembered that Wanklyn's process tells us nothing as to the exact amount or specific nature of the pollution, or whether it is injurious or harmless. The solid matters of enteric or choleraic excreta probably do not greatly differ as regards their yield of albuminoid ammonia from those of healthy excreta, and minute proportions of either one or the other intentionally added to water in experiments by Cory and Dupré caused, as was to be expected, only a proportionately trifling addition to the albuminoid ammonia already present. Such minute but deadly pollutions, by enteric virus or any other poison, rarely occur in nature, but when they do, chemical analysis will give us no intimation of them. Hence it is true that chemical analysis "can tell us of impurity and hazard, but not of purity and safety" (*Buchanan*); but to this it should be added that the circumstances are rare indeed in which a careful consideration of all the analytic data, together with a study of the source of supply and its surroundings, will fail to give warning of any danger that may exist.

The summary on page 87 is slightly modified from

a table given by Parkes and De Chaumont. It shows in a general way the value to be attached to each analytical datum *per se*, but it will be evident that the interpretation is subject to material modification according to the other information available.

Bacteriological examination is the most delicate and direct test of the *safety* of a water for drinking purposes, for by it we obtain information as to its potentiality to cause infective disease. Further, Klein and others have shown that by bacteriological methods it is possible to detect smaller degrees of sewage pollution than by chemistry. On the other hand, it is, of course, idle to expect to learn the exact chemical constitution of the water by bacteriological methods. Like chemistry, bacteriology must be judged by what it can tell us and not by what it cannot. There are three important groups of facts obtainable by a thorough bacteriological examination of water. These concern (*a*) the number of bacteria per c.c.; (*b*) the presence of any organisms of contamination; and (*c*) the presence of any specific organisms of disease. The number of bacteria per c.c. is, as a rule, only valuable when used in a series of examinations of the same water supply, or when used in the examination of water before and after filtration. The number of bacteria per c.c. is therefore a fact of only relative importance, because there is no standard of how many organisms should be present in each c.c. of a potable water, and there is no means by which the number can be accurately measured. For purposes of comparison it may be said that the metropolitan water supply, as consumed, usually contains less than 20 bacteria per c.c.

The organisms which indicate contamination of a water are certain liquefying bacilli, *B. coli*, *B. enteritidis sporogenes*, and streptococci. The chief of these as an indicator is *B. coli*. It is now held that if this

Synopsis of Characteristics of Good and Bad Waters.

Data.	Pure Water.	Usable Water.	Suspicious Water.	Impure Water.
A. Chemical (*in parts per million*):				
1. Total dissolved Solids .	Under 100.	Under 400.	400 to 700.	Over 700.
2. Loss in do. on ignition .	Under 15. (*Solids should scarcely blacken on ignition.*)	Under 40. (*Solids may blacken slightly on ignition, but no fumes should be given off.*)	Over 40. (*Much blackening, or nitrous fumes given off.*)	Over 70. (*Much blackening, with nitrous fumes, or smell of burnt horn.*)
3. Chlorine	Under 15.	Under 50.	Over 50.	Over 100.
4. Nitrites	nil.	nil.	Present.	Marked.
5. Nitrates	nil, or trace only.	Present.	Marked.	Large.
6. Hardness, Permanent .	2° Clark.	Under 4° Clark.	Over 4° Clark.	Over 6° Clark.
7. Ammonia, Free . .	Under 0·02.	Under 0·05.	Over 0·05.	Over 0·10.
8. Ammonia, Albuminoid .	Under 0·05.	Under 0·10.	Over 0·10.	Over 0·15.
9. Organic Carbon . .	Under 1·0.	Under 2·0.	Over 2·0.	Over 3·0.
10. Organic Nitrogen . .	Under 0·2.	Under 0·3.	Over 0·3.	—
11. Oxygen taken from Acid Permanganate	Under 1·0.	Under 1·5.	Over 1·5.	Over 2·0.
12. Sulphides (Forchammer)	nil.	nil.	nil.	Present.
13. Metals . . .	nil.	Trace of iron.	Trace of iron.	Much iron. Presence of other metals, especially lead.
B. Physical:				
1. Transparency . .	Clear, bright.	Clear, bright.	Turbid.	Turbid.
2. Suspended Matter . .	nil.	nil, or separable by subsidence or course filtration .	Much.	Much.
3. Colour	nil.	faint blue or green tinge only.	Yellowish tinge.	Yellow.
4. Taste	Palatable.	Palatable.	Any marked taste.	Any marked taste.
5. Smell	nil.	nil.	nil.	Any marked smell.
6. Microscopic Characters of Sediment . .	nil, or as in next column.	Mineral matter. Vegetable forms with endochrome. Large animal forms. No organic débris.	Colourless vegetable forms. Organic débris. Fibres of cloth, or other evidence of	Abundant animal and vegetable forms. Fungi. *Beggiatoa.* Epithelial scales. Evidences of sewage.

bacillus can be detected in 1 c.c. or 2 c.c. of a water, the organism has gained access recently from sewage. Its relative abundance is a matter of importance. Houston considers the presence of streptococci in water as indication of recent and dangerous pollution. The presence of any pathogenic organisms (*B. typhosus*, the cholera bacillus, etc.), in however few numbers, is, of course, sufficient for the condemnation of a water. Such organisms are rarely isolated from water, even though for external reasons it be evident that the water is the channel of infection, owing to the long incubation period of typhoid fever, the fact that the bacillus only lives in water for a few days, and the impossibility as a rule of examining the water which actually caused the outbreak.

By way of summary, it may be said that a water should be condemned, as a rule, (*a*) if it contains a very large number of bacteria of whatever kind; (*b*) if it contains *B. coli communis*, *B. enteritidis sporogenes*, *streptococci*, or any pathogenic organism, in however small a quantity; (*c*) if it gives the "enteritidis change" in milk cultures, or ferment sglucose or lactose media. In addition to the chemical and bacteriological findings, the careful microscopic examination of the sediment and the thorough inspection of the gathering grounds, the source and course of the water, are necessary. In many ways the latter is the most important part of an examination of a water, and when in doubt as to chemical and bacteriological characteristics, topography may not unfrequently throw light upon the subject.

Drinking Water and Disease.—The relation of drinking water to typhoid and cholera will be considered subsequently. Here it is only necessary to add a general note.

Vegetable matter in suspension and even in solution may cause diarrhœa. In small quantity, however, dis-

solved peaty matter is harmless, although it gives a brownish tinge to the water.

Animal matter in suspension or solution, whether due to percolation from cesspools, leaking drains, farm-yards, or manured fields, or to direct pollution of streams by drains or sewers, or to presence of decomposing animal tissues in the water, or to absorption of effluvia, is always dangerous to health.

The products of simple decomposition of animal matter are in themselves capable of producing diarrhœa and other acute alimentary disturbances, or of insidiously undermining the general health, and so possibly preparing the way for other diseases not directly dependent upon water-borne poison. In tropical countries polluted water is a frequent cause of dysentery, sporadic or epidemic. Many sudden localised outbreaks of diarrhœa in Great Britain have been proved to originate in contamination of drinking water by effluvia from sewage, even without the entrance of liquid or solid filth. Apart from all this, the presence of organic filth in water shows that the way is open for the access of more specific poisons, such as those of cholera, enteric fever, dysentery, and parasitical diseases. The tendency of any such pollution is to increase in amount, while percolation through soil loses in course of time whatever purifying effect it may possess at first.

There are also certain disease conditions produced by water owing in part to its chemical constitution, as, for example, goitre, plumbism, rickets, urinary calculi, etc.

CHAPTER IV.

FOOD.

THE useful constituents of all food substances, animal, vegetable, and mineral, are classified as—

1. Nitrogenous, including the animal and vegetable albuminoids (proteids) and gelatin.
2. Fatty, including animal and vegetable fats and oils.
3. Carbohydrates, including starch and the sugars.
4. Salts, organic and inorganic.
5. Water.

Nitrogenous food.—Proteids are converted by the action of the gastric and pancreatic juices into soluble peptones, which are absorbed and used for the nutrition and repair of the nitrogenous tissues, and in some degree for the production of heat and the functional activity of the system. During life the nitrogen is eventually eliminated in the urine (as urea or urates), and in the fæces. Fat is another product of the splitting-up of albumen, and its hydrogen and carbon ultimately go to form carbonic acid and water. Muscular exertion does not increase the demand for nitrogen or the excretion of urea, these being fairly constant in a given healthy individual under suitable diet, whether working or not. Assimilation of excess of nitrogen, in the absence of exercise, is apt to lead to imperfect oxidation, with formation of urates and uric acid rather than urea. Other consequences are engorgement of the liver and general plethora, pyrexia, tendency to diarrhœa, and ultimately to a gouty condition.

Deficiency of nitrogen leads to diminution of circulating albumen, anæmia, loss of weight, and impairment of energy and stamina. Ultimately the tissue albumen, and especially that of the muscles, is reduced.

Nitrogenous food is therefore essential for the growth, maintenance, repair, and functional activity of the tissues, and contributes in some measure to the production of heat and force.*

Fats and carbohydrates supply the oxidisable material for the production of heat and force, and are ultimately eliminated as carbonic acid and water. They aid in the nutrition of the tissues and in the excretion of waste material. An excess of either lessens oxidation of nitrogenous matter and leads to storage of fat in the tissues ; deficiency causes increased metabolism of circulating albumen, loss of weight, and impairment of nutrition. Sugars, starches, and certain other substances are termed *carbohydrates*, because their molecule contains (besides carbon) twice as many atoms of hydrogen as of oxygen, and may therefore be represented empirically as $C_x(H_2O)_n$, or carbon *plus* water. Glucose is $C_6H_{12}O_6$, cane sugar $C_{12}H_{22}O_{11}$, and starch $C_6H_{10}O_5$. Fats and oils (animal or vegetable) contain much less oxygen in proportion to their carbon and hydrogen, stearin, for example, being $C_{21}H_{40}O_6$. Carbohydrates are more readily assimilated than fats, but have a lower nutritive value by at least 40 per cent. They are converted into grape-sugar by the digestive processes. As a rule, nutrition ultimately suffers if either fats or carbohydrates are withheld; but to a certain extent they are interchangeable, and the diet of the Eskimo contains little or no carbohydrate.

Fat as a tissue is useful for its mechanical properties—namely, non-conduction of heat, lubrication, and soft elastic pressure ; in excess it becomes a source of inconvenience or danger, as in extreme obesity and in fatty infiltration of the heart.

* Gelatin appears to be capable of replacing the circulating albumen, but not of forming tissue albumen or repairing its waste. Its nutritive value is said to be about one-fourth of that of albumen. Digestion converts it into a sort of peptone, which does not gelatinise.

Even more than this is actually consumed sometimes. Brickmakers for instance have been found to consume food to the value of 8,848 calories. Rubner, however, states the average as 3,644. For hard work all the chief constituents of food may be increased, but there is evidence to show that the most valuable source of muscular energy are the carbohydrates. For mental work the digestibility of food is of greater concern to the brain worker than chemical composition (*Hutchison*). Reduction on a muscular diet should, however, affect fats and carbohydrates more than proteids. As already remarked, age and sex exert a marked influence upon dietetic requirements. The same must be said in respect of climate, season, and personal peculiarity.

From the chemical standpoint authorities suggest that a daily dietary for a male adult should be composed somewhat as follows :—

	Nitrogenous Food.	Fat.	Carbohydrates.	Salts.	Such a diet would contain	
					Nitrogen.	Carbon.
Rest	3 oz.	1½ oz.	12 oz.	1 oz.	200 grs.	4000 grs.
Moderate work .	4½ ,,	3 ,,	15 ,,	1¼ ,,	300 ,,	5000 ,,
Hard work .	6 ,,	4½ ,,	18 ,,	1½ ,,	400 ,,	6000 ,,

These amounts are only approximate. The necessity for so great an increase of nitrogen during hard work is open to question, and on the other hand the hard work standard of carbon in the above table is low. More food, especially fat, is needed in cold climates, less in hot.

All the ingredients are supposed to be water-free, but would, in practice, be combined with at least their own weight of water, raising the total daily weight of solid food to 40 or 50 oz. In addition to this 50 to 80

oz. of water are taken as drink. A man consumes daily about $\frac{1}{100}$ of his weight of *dry* solid food and $\frac{6}{100}$ of water. Women are said to require about 10

Chemical Composition of Certain Food Substances.
(*Parkes.*)

	Per Cent of					Grains per lb.	
	Water.	Nitrogenous.	Fatty.	Carbohydrates	Salts.	Nitrogen.	Carbon.
Good meat,* beef or mutton, with little fat (uncooked)	75	20	3·5	...	1·5	190	1900
Average meat* (uncooked)	75	15	8·5	...	1·5	...	..
Roast meat	55	28	15		3	..	.
Very fat meat*	63	14	19	...	4	...	
Fat pork	40	10	50	...	2·	100	4000
Salt pork†	45	25	7	...	25	290	1360
Salt beef†	50	30	0·2	...	20	325	1115
White fish	78	18	3	...	1	200	875
Eggs	74	14	11·5	...	1	..	.
New milk	87	4	3·5	5	0·5	45	600
Skim milk	90	4	2	5	0·8	45	450
Cheese	37	33	24	.	5·5	300	3300
Butter	6	0·3	90	.	2·5	.	6500
Bread	40	8	1·5	50	1·5	90	2000
Flour	15	11	2	70	1·7	120	2700
Oatmeal	15	13	6	65	[illegible]	140	2800
Indian meal	14	10	7	65	1·5	120	3000
Peas (dry)	15	22	2	55	2·5	250	2700
Green vegetables	90	0·2	0·5	6	0·7	14	420
Carrots	85	0·6	0·2	8·5	0·7	14	500
Potatoes	75	1·5	0·1	23	1	22	770
Rice	10	5	0·8	83	0·5	70	2700
Sugar	3	...	...	96	0·5	...	3100‡

* 20 per cent. should be allowed for bone, and 20 to 30 per cent. more is lost in cooking.

† Brine dissolves out myosin and other important constituents. The nutritive value of salt meat is not more than $\frac{2}{3}$ that of fresh meat.

‡ Milk-sugar yields only 2,800 grains of carbon per lb.

per cent. less than men, both of carbon and nitrogen. Infants require nitrogenous and fatty foods with only a small proportion of carbohydrates, which is supplied by milk-sugar. A child of ten years of age needs only half as much, but at fourteen years quite as much, as a woman. The dietetic requirements of old age are just the reverse of those of childhood.

The table on page 85 supplies the means of determining how far a given dietary complies with the requirements stated above, and conversely of constructing a dietary that will satisfy these conditions.

Thus, if the question should arise whether a daily allowance of 2 lbs. of bread and ½ lb. cheese is a sufficient diet for a man in easy work, the calculation may be made on a chemical basis as follows :—

	Nitro.	Fat.	Carb.-hyd.		Nitro.	Fat.	Carb.-hyd
100 oz. bread contain	8 oz.	1½ oz.	50 oz.	therefore 32 oz. contain	2·5 oz.	0·5 oz.	16 oz.
100 oz. cheese contain	33 oz.	24 oz.	0 oz.	therefore 8 oz. contain	2·6 oz.	1·9 oz.	0 oz.
					5·0 oz.	2·4 oz.	16 oz.
Whereas the theoretical amounts required for moderate work are . .					4·5 oz.	3 oz.	15 oz.

The conclusion to be drawn is that such a diet is sufficient as regards the nitrogenous matter and carbohydrates, but wanting in fat.

A still readier method is to calculate the amount of carbon and nitrogen, thus :—

	Nitrogen.	Carbon.		Nitrogen.	Carbon.
1 lb. bread contains	90 grs.	2000 grs.	therefore 2 lbs. contain	180 grs.	4000 grs.
1 lb. cheese contains	300 grs.	3300 grs.	therefore ½ lb. contains	150 grs.	1650 grs.
				330	5650
The theoretical amounts of carbon and nitrogen required for moderate work being				300	5000

Hence, if we leave out of consideration the differences between fats and carbohydrates the diet more than satisfies the theoretical requirements.

The problem may also be presented the other way round. What quantity x of bread and y of cheese would be sufficient for an ordinary diet? The requirements are 300 grains of nitrogen, and 5,000 of carbon; and x lbs. of bread contain $90 \times x$ grains of nitrogen and $2{,}000 \times x$ grains of carbon, while y lbs. of cheese yield $300 \times y$ grains of nitrogen and $3{,}300 \times y$ grains of carbon. Hence we have a simultaneous equation—

$$\begin{aligned} 90x + 300y &= 300 \\ 2000x + 3300y &= 5000 \end{aligned}$$

giving as approximate values $x = 1{\cdot}7$ lb., and $y = \frac{1}{2}$ lb.

It has been found experimentally that the energy which is developed by oxidation is for one ounce of lean meat about 50 foot-tons,* carbohydrates 150 foot-tons, and fats 300 foot-tons. In this relation it should not be forgotten that the oxidation of food in the system is by no means complete, even as regards that portion which is assimilated.

In calculating the **mechanical work** done, that of respiration, circulation, and locomotion must be taken into account, as well as the load carried or lifted. According to Haughton and Parkes the force exerted daily in respiration, circulation, and other "internal" work is about 260 foot-tons; and in addition to this a strong man can do external work equivalent to 300 to 500 foot-tons more per day. Walking along a level road at three miles per hour is equivalent to climbing vertically $\frac{1}{20}$th of the distance traversed; at 4 miles $\frac{1}{17}$th. Hence, if a man weighing W lbs. carries a load of X lbs. on a horizontal track for D feet, at

* A *foot-ton* is the force required to raise 1 ton to a height of 1 foot.

3 miles per hour, he exerts energy equivalent to $\frac{(W+X)D}{20 \times 2240}$ foot-tons in so doing. A march of 20 miles along the level involves work equivalent to 350 foot-tons, taking the weight of the body as 150 lbs. If a load of 60 lbs. is added, the work is 500 foot-tons. The whole work done, estimated in this way, represents only $\frac{1}{7}$th of the force theoretically obtainable from the food by combustion. The energy expended in a fair day's work is about one-fifth mechanical labour to four-fifths heat (*Martin*).

Animal is generally held to possess certain advantages over vegetable food, of which the most certain are the ready supply of blood-pigment, the larger percentage of proteids, the greater digestibility of animal fats, and the smaller bulk required. A vegetable dietary, unless carefully selected, is apt to contain insufficient nitrogen, but it is rich in carbohydrates. It is, however, bulky, less digestible in the stomach, and less completely absorbed. The supposed inferior nutritive value of vegetable albuminoids is not so clear, although they are probably less rapidly digested; and a well-fed vegetable eater may display for a time as perfect health and energy as a meat-eater.* On the other hand, the argument from analogy with the herbivora, some of which are types of activity, loses weight from the inability of man to digest cellulose. The consistent vegetarian must either live on a diet deficient in proteid or consume an excessive bulk of food. The adoption of the former course tends to diminish energy and tissue resistance, and the latter is likely to lead to derangement of the digestive organs.

Morbid conditions dependent upon diet.—An excess of food, due to too large or too frequent meals,

* Vegetarianism as ordinarily practised does not exclude animal fats, or even albuminoids; milk, butter and cheese being used freely.

may accumulate in the intestine, causing fermentation and also dyspepsia, with constipation or ineffective diarrhœa. Gout, obesity, gall stones and other conditions may also arise from excess of food. Absorption of the products of putrefaction may give rise to a septic condition marked by pyrexia, furred tongue, fœtid breath, heaviness, and possibly jaundice. Diseases of the blood may also arise from retention of waste products in the intestine, as for instance when chlorosis follows constipation. The effects of excessive or deficient assimilation of nitrogenous and carbonaceous food have already been considered.

Protracted insufficiency of diet is followed by wasting of the tissues (*inanition*). Adipose tissue is naturally the first to suffer, and may be almost completely absorbed, the other tissues following mainly in the inverse order of their importance to life. The urine still contains urea and urates, from oxidation of tissue, first of the circulating albumen, afterwards of tissue albumen. Physical and mental weakness ensue, followed by anæmia and an adynamic condition that powerfully predisposes to certain diseases, notably relapsing fever, phthisis, and pneumonia, and perhaps to all infectious diseases. Diarrhœa is apt to occur, adding still further to the general emaciation and prostration. Ophthalmia, stomatitis, ulcers, and skin diseases of various kinds, are common, and any disease that may have obtained a hold upon the system is aggravated by the impairment of nutrition. Death ensues when the loss reaches about 40 per cent. of the normal weight of the body.

Apart from parasitic poison and infection, there are two well marked morbid conditions that are almost always attributable to the absence of essential elements of diet. These two are rickets and scurvy

Rickets rarely occurs in children fed upon milk in which there is not undue admixture of starchy foo

provided only that digestion is not deranged. Starch cannot be digested by infants under seven months, and its administration is not only useless but liable to cause diarrhœa, which interferes with the digestion of other food. Even apart from this, an excess of starch or other carbohydrate has an injurious effect upon nutri tion.

Scurvy does not occur when the diet includes plenty of fresh vegetables and fruits or their juices, or even preserved vegetables and fruits. The blood or raw flesh of recently killed animals is credited with considerable anti-scorbutic power. Citrate, tartrate, and malate of potash are also preventives, and, to a less degree, lactate and acetate. Carbonate of potash is inert. The disease affects under-fed men more readily, but cannot be checked by increase in the supply of nitrogenous food, carbohydrates, or fat. The fault probably rests with the supply of salts, and as scurvy occurs when there is no lack of phosphates or sodium chloride, potash and organic acids alone of the ordinary salines are missing. The salts of organic acids differ from those of mineral acids in one important particular—namely, their oxidation in the blood to form carbonates with alkaline reaction, although they may have been neutral or acid originally. Thus the citric acid and citrate of potash, which are the principal constituents of lime-juice, are oxidised into carbonic acid, which is removed by the lungs, and (alkaline) potassium carbonate. Potatoes are efficient anti-scorbutics, and contain a large proportion of organic acid, salts of potash, soda, and lime. The absence of land scurvy at the present time may not unreasonably be attributed in great measure to the universal use of potatoes, and other fresh vegetables and fruits, as articles of food.

Meat varies considerably in its nutritive qualities according to the age of the animal, the state of its

nutrition at the time of slaughter, and the proportion of fat. Well-fed prime meat contains more albuminoids and less connective tissue than that which is taken from animals that are badly fed, diseased, or too old or too young. The proportion of fat, roughly speaking, ranges from 50 per cent. in fat pigs or sheep to 33 per cent. in fat oxen or lambs, and 16 per cent. in calves. Absence of fat is largely compensated for by presence of additional water, so that the nitrogen remains fairly constant. As a rule, "white meat," such as fowl and rabbit, is less nitrogenous, more tender, and more digestible than "red meat," such as beef, mutton, and game. The latter become more tender if kept until *rigor mortis* gives place to incipient putrefactive changes.

Relation to disease.—The flesh of animals suffering from any inflammatory disease is watery and innutritious, discoloured, possesses a stale odour, and decomposes rapidly. The use of such meat is liable to cause alimentary disturbance. The same applies, more or less, to animals emaciated from any cause. In some persons acute dyspepsia and diarrhœa are caused by apparently normal meat of certain kinds, usually pork or mutton. As a rule, meat in any stage of putrefaction (the signs of which are smell, discoloration, and loss of elasticity) is liable to cause acute gastro-intestinal irritation, and other manifestations of septic poisoning, the prominent symptoms being vomiting, diarrhœa, cramps, prostration, pyrexia, with weak and irregular pulse. Frequently meat in an early stage of decomposition is more toxic than when more advanced. It is not, however, easy to account for the impunity with which certain kinds of food, venison and game for instance, are habitually consumed in a state of early decomposition. It is probable that the toxic products are not present in anything like the same degree as in ordinary w-

common. The usual symptoms include rigors, faintness, vomiting, diarrhœa, abdominal pain, and occasionally skin eruptions. As a rule, certain nervous conditions have supervened, such as giddiness, headache, paralysis, mental depression, etc., and occasionally these symptoms have been predominant.

Date of Occurrence.	Place of Occurrence.	No. of Cases.	Period of Incubation in Hours.	Probable Source of Infection.
1880	Welbeck	72	12–48	Cold boiled hams
1881	Nottingham	15	12–34	Pork
1882	Oldham	9	4	American tinned pig's tongue
1882	Bishop Stortford	6	24	Beef
1882	Whitchurch	20	1–5	Brawn
1886	Carlisle	20	6–40	Ham & game pie
1886	Ironbridge	12	6–12	Veal pies
1887	Retford	80	8–36	Pork brawn
1888	Middlesbrough	114	..	American bacon
1889	Carlisle	25	24	Pork pies
1891	Portsmouth	13	14–17	Cold meat pie
1896	Mansfield	265	18–24	Potted meat
1898	Oldham and Chadderton	54	48	Veal pies
1899	Nuneaton	42	12–48	Pork
1899	Sheffield	24	2–3	Corned beef
1902	Derby	221	4–24	Pork pie

Meat poisoning appears to depend not upon the number of bacteria present in the meat, but upon the particular species (that is, *bacterial infection*), and their products (ptomaines, toxins, that is, *ptomaine-poisoning*). A long incubation period generally indicates poisoning by bacteria (an infection), and a short incubation period poisoning by products (an intoxication). In 1888, Gaertner of Jena investigated an outbreak of disease affecting 58 persons who had eaten uncooked meat. One victim died, and from his body, as well as from the meat, Gaertner isolated the *B. enteritidis*, an organism allied to the coli group. This was practically the starting-point of accurate

bacteriological investigation into this group of epidemics. Since that period, the *B. botulinus* of Ermengem, *B. enteritidis sporogenes* of Klein, and certain putrefactive bacteria, particularly of the coli group (p. 57), have been held responsible for causing such illnesses.

B. enteritidis (*Gaertner*). Characters similar to *B. typhosus* (morphology, motility, and staining properties), but grows more rapidly in gelatine; fewer flagella; ferments lactose and sometimes dextrose; does not produce indol or coagulate milk; positive neutral-red reaction; in litmus whey or litmus broth, acid is first produced, and then the medium becomes distinctly alkaline. Virulent to rodents and small animals (gastro-intestinal symptoms, hæmorrhagic enteritis and swelling of lymph follicles). Forms no spores, and therefore cannot stand very high temperatures. (Killed at 70° C. in one minute.) It produces agglutinating properties in the blood of the patient.

B. botulinus (Ermengem). Van Ermengem describes, under the name of botulism, a state brought about by the ingestion of various articles of food, such as ham, tinned or preserved foods, oysters, mussels, etc., and which is characterised by comparatively slow onset (twelve to twenty-four hours after infection), secretory troubles, paralysis of certain muscles, particularly of tongue and pharynx, dilatation of pupil, aphonia, dysphagia, constipation, retention of urine, absence of unconsciousness and of fever, etc. Botulism differs considerably from the more common form of food-poisoning with which we are acquainted in England, and which is characterised by practically the same symptoms as those of epidemic diarrhœa. *B. botulinus* is 4-9μ long and ·9-12 μ broad; round, slowly motile, 4-9 flagella. Polar spores, killed in thirty minutes at 80° C. Liquefies gelatine; does not coagulate milk; anaërobic; in cultures often produces gas and a sour, rancid odour. Pathogenic for guinea-pigs, rabbits, and other small animals.

B. enteritidis sporogenes of Klein (*see* Epidemic Diarrhœa).

The *B. enteritidis Derbiensis* is a member of the Gaertner group, isolated by Delépine from pork pies the consumption of which caused the Derby outbreak in 1902. He considered the presence of the bacillus in the pork pies was due to contamination of the meat before it was cooked, and that the central parts

of the pies were not thoroughly cooked. It frequently happens in these cases that some constituent part (such as jelly) of the manufactured article or prepared dish is really the polluted portion. Experience of meat poisoning outbreaks leads to the conclusion that the meat has contracted its poisonous properties in one or all of the following ways, viz., putrefaction or unsoundness in the meat itself, unclean manipulation or storage in insanitary places, and insufficient cooking. The methods of prevention are therefore obvious. Occasionally tinned goods cause poisoning, owing to metallic absorption, and this must be differentiated from bacterial poisoning.

Tuberculosis.—This disease is set up in animals by the tubercle bacillus, which is either identical or nearly allied to the *B. tuberculosis* of Koch.

Tuberculosis is common among cattle, especially if stall-fed, and is increased by the practice of housing them with inadequate air-space and ventilation. Out of 23,000 cattle slaughtered at Leipzig in 1895, tuberculosis was found in 33 per cent. The tuberculin test has revealed the presence of tuberculosis in 54 per cent. of the cows of certain breeds in certain dairies in Great Britain.

Investigations carried out in 1902 in all the chief breeds in this country have shown that 14·7 per cent. are affected with tuberculosis (*Geddes*). Probably the general average is about 15-20 per cent. In London and other large cities, where a high degree of inspection is maintained, and where there is no in-breeding, only about 0·2 per cent. of the cows are tubercular.

It has long been customary to condemn as unfit for food all parts of a carcase in which tubercle is found, and the whole carcase if the disease be far advanced and the animal emaciated. Following the conclusions of the Paris Congress of 1888 many

authorities have adopted a more stringent standard, and condemn the whole carcase if there be any tubercle in any part, no matter how slight or localised.

The Royal Commission on Tuberculosis reported in 1898 as follows :—

"The following principles should be observed in the inspection of tuberculous carcases of cattle :—

(*a*) When there is miliary tuberculosis of both lungs . (*b*) When tuberculous lesions are present on the pleura and peritoneum . . (*c*) When tuberculous lesions are present in the muscular system, or in the lymphatic glands embedded in or between the muscles (*d*) When tuberculous lesions exist in any part of an emaciated carcase . .	Generalised tuberculosis is present, and the entire carcase and all the organs may be seized.
(*a*) When the lesions are confined to the lungs and the thoracic lymphatic glands (*b*) When the lesions are confined to the liver . . (*c*) When the lesions are confined to the pharyngeal lymphatic glands . . (*d*) When the lesions are confined to any combination of the foregoing, but are collectively small in extent	Localised tuberculosis is present, and the carcase, if otherwise healthy, shall not be condemned, but every part of it containing tuberculous lesions shall be seized.

"In view of the greater tendency to generalisation of tuberculosis in the pig, we consider that the presence of tubercular deposit in any degree should involve seizure of the whole carcase and of the organs.

"In respect of foreign dead meat, seizure shall ensue in every case where the pleuræ have been 'stripped.'"

The tubercle bacillus is most easily found in the glands, and tuberculous deposits in the muscles are very rare. The bacillus is scarce in the caseating nodules. In the pig it is difficult to detect the bacilli as a rule, though the disease is very common in that animal, affecting chiefly the abdominal organs and the glands of the throat. It is rare in the sheep. The Royal Commission reported that "in tissues which go to form the butcher's joint, the material of tubercle is not often found even where the organs (lungs, liver, spleen, membranes, etc.) exhibit very advanced or generalised tuberculosis; indeed, in muscle and muscle juice it is very seldom that tubercle bacilli are to be met with; perhaps they are somewhat more often to be discovered in bone, or in some small lymphatic gland embedded in intermuscular fat." The chief way in which such meat substance becomes infected with tubercle appears to be through carelessness in the butcher, who perchance smears the meat substance with a knife which has been used in cutting the organs, and so has become contaminated with infected material. "Ordinary cooking, such as boiling and more especially roasting, though quite sufficient to sterilise the surface, and even the substance for a short distance from the surface of a joint, cannot be relied upon to sterilise tubercular material included in the centre of rolls of meat, especially when these are more than three pounds or four pounds weight. The least reliable method of cooking for this purpose is roasting before a fire; next comes roasting in an oven, and then boiling." (*Sims Woodhead.*)

It should be added that whilst it is evident that tuberculosis is not greatly spread by the consumption of tuberculous meat, the Royal Commission of 1895

definitely concluded that "we must believe that any person who takes tuberculous matter into the body as food incurs some risk of acquiring tuberculous disease." In spite of Koch's views to the contrary, which are discussed subsequently, that conclusion still represents, broadly, the views of most authorities.

Characters of good meat.—It should be firm and elastic, but not tough, and it should not "pit" on pressure; a thin red meat juice (acid) will often exude in small quantity on standing; the meat substance should be red throughout, not pale, purple, or green marbled by layers of fat; free from purulent or gelatinous fluid in the septa between the muscular bands fresh and pleasant in smell, as tested by a clean skewer; which has been plunged into the interior. The reaction should be slightly acid. The meat should "set" within twenty-four hours.* The flesh is pale in pork, in young animals, and in those suffering from exhausting diseases; dark in old animals, or those which have died with the blood in them, or in inflamed parts; wet in dropsy, and often in inflammatory diseases. With commencing putrefaction the colour becomes pale, and the smell disagreeable; later the meat softens in parts and turns green.

The liver, lungs, heart, and flesh should be examined for parasites; the head, stomach, and intestines for evidences of specific disease. The microscope would detect *Cysticerci* (usually visible to the naked eye) and *Trichinæ* in muscle, and *Stephanurus dentatus* in the brain. To demonstrate *Trichinæ*, a thin section should be put into liquor potassæ for a few minutes only until the muscle becomes translucent. The coiled embryo will be seen inside the capsule.

* Horse flesh may be differentiated from beef by the following characters: It does not set so rapidly or so well. It is more tendinous and fibrous, contains less fat, which is oily and yellow, and possesses a horsey smell. The colour is also more brown-red and less bright than in sound beef.

The fat should be firm, white, and free from hæmorrhages ; not yellow or gelatinous.

Fat consists of olein, palmitin, and stearin, which are respectively oleic acid, palmitic acid, and stearic acid, combined with glycerine as a base. Stearin, $\left.\begin{matrix}(C_{18}H_{35}O)_3\\C_3H_5\end{matrix}\right\}O_3$, melts at about 65° C.; palmitin, $\left.\begin{matrix}(C_{16}H_{31}O)_3\\C_3H_5\end{matrix}\right\}O_3$, at a variable point between 35° C. and 60° C.; olein, $\left.\begin{matrix}(C_{18}H_{33}O)_3\\C_3H_5\end{matrix}\right\}O_3$, at 5° C. Fats with a high melting point, such as mutton fat, consist mainly of stearin; those with a low melting point, such as bacon fat, principally of olein.

Sausages are liable to convey the same diseases as the meat from which they are made, but there are no longer any macroscopic signs to guide us. In a fatal case at Chester, investigated by Ballard, violent symptoms of gastro-intestinal irritation came on within half an hour of eating sausage, which was found to contain an organic chemical poison. There have since been similar cases. Decomposition may be detected by the smell, which is made more obvious by adding hot water and lime-water.

Preservation of meat may be effected for a time :

(1) By exclusion of air. The meat is dipped into boiling water so as to form an impervious layer of coagulated albumen on the surface ; or coated with paraffin, or simply with fat.

(2) By injection of preservative solutions. The blood-vessels are injected first with water, then with a solution of alum and aluminium chloride—or even sodium chloride.

(3) By application of preservatives to the surface. The meat may be covered with salt, sugar, boracic acid, boroglyceride, powdered charcoal, weak carbolic acid, or other fixed antiseptic. Or it may be kept in a closed vessel containing volatile oils or antiseptics.

(4) By pickling. Common salt, with a little potassium nitrate, is rubbed into the meat, or the latter is immersed in strong brine. Water is abstracted, and the salt acts as a preservative.

(5) By drying. Meat is exposed in somewhat thin layers to dry air, or, still better, to the smoke from a wood fire.

(6) By continuous exposure to cold (*freezing*). Meat can be kept in a cold-air chamber for an indefinite period, but decomposes rapidly upon thawing if *rigor mortis* had set in before freezing. It is better to keep the temperature a little above freezing-point (*refrigerated* or *chilled* meat), as actual freezing has certain disadvantages.

(7) By hermetically sealing in tin cases or other vessels *in vacuo*, or in sterilised air. Various devices are adopted to sterilise the contents of the tins. Before sealing, air may be drawn off and replaced by nitrogen and sulphurous acid, or by air which has been heated to 500° F., or by steam. Other processes aim at complete exclusion of air, or exclusion of part and removal of oxygen from the remainder by means of sodium sulphite, or at exclusion of all germ life by boiling.

The dangers attending the use of preserved meat are those depending upon the original character of the meat, already referred to, together with risk of putrefaction if the process is imperfectly carried out. Tinned meat sometimes gives rise within twelve hours to symptoms of acute gastro-intestinal irritation, viz. vomiting, purging, cramps, some degree of pyrexia, irregular pulse, and prostration. These ill effects may result from decomposition due to imperfections in the process; and in this case the tin will show signs of pressure in place of the usual vacuum ("blown" tins), and the meat may have an offensive smell and

taste. Not unfrequently, however, no such changes are noticed, but salts of tin, zinc, or lead are found in the meat and jelly, due, no doubt, to the action of sodium chloride or organic acids upon the tin or solder, perhaps aided by galvanic action.

Cooking brings about coagulation of the myosin and other albuminoids, renders the meat soft and tender by converting the connective tissue into gelatin, and reduces the amount of water and extractives. Boiling in the ordinary way causes a loss of 25 per cent. or more, but most of the salts and soluble substances may be retained by plunging the meat for five minutes into boiling water, and then continuing the cooking at a low temperature. The loss is greater in roasting than in baking, and least in boiling. The various albuminoids coagulate at temperatures ranging from 85° to 170° F., hæmoglobin at 160°. If, therefore, the temperature at any part does not reach 160° the meat is underdone; and if it exceeds 170° the tissues shrink and become hard and indigestible. The best temperature is about 160°. Roasting also entails a loss of about 25 per cent., but mainly of water, with some fat and a little gelatin. It is advisable first to expose meat to an intense heat and afterwards cook it slowly. Ordinary cooking or pickling affords little protection in meat infected with specific virus.

Meat Inspection.—The effectual inspection of meat really requires (*a*) veterinary inspection of animals before slaughter, and (*b*) systematic inspection in some form of clearing-house of all market meat. In the absence of these two requirements, meat inspection must necessarily be incomplete. In some countries there is State inspection, and all marketable meat bears an official stamp. In this country, however, meat inspection rests with the Local Authorities, the larger of which employ meat inspectors specially qualified for the work.

Qualifications of Meat Inspectors.—The L.G.B., in circular letters addressed to local authorities in 1899 and 1901, strongly urged that Meat Inspectors should be directed to act in accordance with the principles laid down by the Royal Commission with regard to the condemnation and seizure of meat affected with tuberculosis (page 107), and, further, that they should possess proper qualifications for the office, including acquaintance with—

(*a*) The law of meat inspection.
(*b*) The names and situations of the organs of the body.
(*c*) Signs of health and disease in animals destined for food, both when alive and after slaughter.
(*d*) The appearance and character of fresh meat, organs, fat and blood, and the conditions rendering them, or preparations from them, fit or unfit for human food.

Any Inspector of Nuisances or Sanitary Inspector to whom either of these orders applies is required in any case of doubt in connection with the inspection and seizure of meat to report the matter to the Medical Officer of Health, with the view of obtaining his advice thereon.

Methods of Inspection.—Cursory inspection will frequently mislead, and it is desirable for the meat inspector to perform his duties in a systematic manner. At the slaughter-house or in the wholesale market meat may be examined as follows (written notes being made) :—

(*a*) *Inspection of the Carcase.*—Note in particular the species of animal, the general character of the carcase, size, weight, emaciation, the condition of the bones, the pleura (and whether "stripped" or not), the peritoneum, the kidneys, the superficial and deep glands, the colour and condition of the flesh (to be judged by the freshly cut surface), staining of the peritoneum owing to decomposition in the intestine, signs of dropsy or inflammation, signs of drugging, etc.

(*b*) *Inspection of the Organs* (*constituting* the

"*offal*").—The head; the heart, lungs and liver ("plucks"); spleen, udder, stomach, and intestines, should each be examined if available.

(*c*) *The Mode of Dressing* the Carcase.—Artificial inflation of emaciated tissues by air, the smearing of fat over the surface of the carcase, stripping of the membranes, skilful dressing of the carcase, and evident preparation of it for market, should all be noted. Sometimes methods are adopted to disguise the real condition of meat on the one hand, and, on the other, meat for human consumption is dressed to a marketable standard.

(*d*) *Miscellaneous.*—In addition to the condition of the meat itself, there are other matters not to be neglected by the meat inspector, such as the price marked upon the meat, whether it was exposed for sale, or deposited for the purpose of sale, or deposited for preparation for sale, the hour at which it was inspected (or subsequently seized), the condition and temperature of the weather, etc. All these may become of importance in any subsequent proceedings.

Mode of Proceeding.—An inspector who comes across unwholesome meat should (*a*) "seize" it, unless it be voluntarily surrendered by the owner taking the initiative, and (*b*) inform the **M.O.H.** If the **M.O.H.** considers the meat unfit for food, (*c*) it should at once be submitted to a magistrate for condemnation and destruction, the owner being permitted to have the meat seen by experts on his behalf if he so wishes. (*d*) The case should be fully reported to the **S.A.**, and instructions taken as to proceedings. The various portions of evidence which may be required in court are as follows:—(i.) A copy of the summons issued by the **S.A.** against the owner of the meat; (ii.) the order signed by the magistrate to the effect that, having examined the meat, he had ordered its destruction; (iii.) the resolution of the **S.A.** or Committee,

signed by the chairman; (iv.) copies of subpœnas; (v.) a clear and concise statement of the inspector's evidence of seizure and the reasons for seizure; (vi.) a statement by the **M.O.H.** as to the pathological condition of the meat in question and its unfitness for human food; (vii.) collateral evidence of medical or veterinary experts, if such are to be called, and of other persons, salesmen, porters, butchers, slaughterers, etc.

Classification of Unwholesome Meat. — Before forming an opinion as to unwholesomeness of meat, it is necessary to decide as to its quality and condition; that is, whether it is fresh home-grown meat or frozen, chilled, salted, or pickled meat. Having assured himself of the conditions under which the meat is being examined, the next step for the meat inspector is to diagnose the disease with which the meat is affected. Broadly, and for practical purposes of meat inspection, these may be divided into three groups—(*a*) General pathological conditions; (*b*) Specific disease; (*c*) Decomposition. Among the first group are conditions of ordinary degeneration of the tissues and inflammation: fatty infiltration, calcification, and infiltration by pigment, as in melanosis and jaundice; cloudy swelling, fatty degeneration, amyloid disease, gangrene, etc.; fevered flesh and the meat of unbled animals that have died or have been slaughtered when in a moribund condition. The last named is blood-stained, sticky, pits on pressure, and possesses a uræmic smell. It rapidly decomposes, and is heavily charged with ptomaines. There are a variety of inflammatory diseases, some of which are doubtless due to specific causes, and others of which the origin is obscure.

Secondly, there are the specific diseases of animals which cause meat to be unfit for food. These diseases are not necessarily transmissible to man, but they produce in the tissues of the animal suffering from them certain poisonous toxins. It should be remem-

bered that in many cases such products occur early in the disease, and not only when it has reached an advanced stage. Among specific diseases for which meat should be seized as unfit for food are tuberculosis, actinomycosis, glanders, anthrax, swine fever, contagious pleuro-pneumonia, septicæmia, cattle plague, and a large number of parasitical diseases.

Decomposition of meat is, of course, a post-mortem change. The rapidity with which the decomposition sets in depends upon many circumstances external to the meat, such as temperature of the air, place of storage, etc. Colour, consistence, and odour are the three chief signs upon which reliance may be placed.

Fish are, as a rule, nutritious and digestible but deficient in fat, though eels contain it in abundance, and salmon and herrings also. Fish should be eaten only in season, unbruised, fresh, firm, and free from offensive smell and disease. Unsound fish is dull in appearance, discoloured, and offensive. The least decomposition renders fish unfit for food, and liable to cause gastro-intestinal irritation if eaten. Similar symptoms occasionally follow the use of apparently sound fish. Consumption of the halibut, and probably of other fish also, has been known to cause diarrhœa and vomiting, and within a few hours a vivid red rash may appear over the upper part of the body, followed by profuse desquamation lasting several days. Fish are largely preserved by the means already referred to, and especially by drying, curing, salting, or canning.

Oysters and Shell-fish.—Oysters eaten raw are readily digested, but other shell fish are as a rule indigestible and not unfrequently cause dyspepsia and urticaria. Mussels are especially prone to be poisonous, the symptoms including not only dyspepsia and urticaria, but also swelling of the tongue and

fauces, numbness of the limbs, and weak, irregular pulse. Severe and often fatal attacks have been attributed to eating mussels gathered upon shores polluted by sewage. Many of the cases of mussel-poisoning are believed to be due to simple acute dyspepsia, but others have been traced to an alkaloidal poison (*mytilotoxine*) contained in the liver of the mussel.

Cockles and periwinkles are usually cooked, but mussels are often eaten raw, and if taken from beds to which sewage has access appear occasionally to have given rise to enteric fever among consumers.

Oysters, under like conditions, have been found to convey enteric fever, and the evidence clearly points to a certain ability to transmit the infection of cholera also. In the spring of 1894 Newsholme attributed a number of cases of enteric fever at Brighton to the consumption of oysters, and in October and November, 1894, a sudden and brief outbreak of enteric fever occurred among the students at Wesleyan University, Connecticut, and was investigated by Conn. In all, 23 of the students were attacked, 13 of the cases being of severe character, and 4 fatal. The other 10 were of very mild type. A consideration of the dates of attack led to the conclusion that infection must have taken place at the time of a series of initiation suppers, and, by exclusion of other possible factors, the one condition common to all sufferers was found to be the eating of raw oysters taken from a certain ground within 100 yards of sewers receiving the drainage of houses in one of which were two persons suffering from enteric fever. Apart from the students, there were a number of guests, two of whom had well-marked enteric fever, and several had less definite diarrhœal attacks. Chantemesse has recorded that in June, 1896, fourteen persons living in six houses at Saint-André-de-Sangonis ate some oysters

which had been stored in sewage-contaminated water. All of these persons, but no other members of their households, fell ill. Six had severe attacks of enteric fever, one ending fatally, but in the other eight the symptoms were slight. Among other microbes, the *bacillus coli* was found in oysters grown under like conditions; and Eberth's bacillus, as well as the colon bacillus, was found in the liquor and in the body of the oysters which had been placed in sea-water purposely contaminated with enteric discharges.

In 1896 Bulstrode and Klein reported to the L.G.B. upon Oyster Culture in Relation to Disease. Experiments by Klein gave results which are thus summarised by Thorne Thorne in the introduction to this Report:

1. The cholera vibrio, and still more, the typhoid bacillus, are difficult of demonstration in sewage known to have received them.
2. Both these organisms may persist in sea-water tanks for two or more weeks, the typhoid bacillus retaining its characteristics unimpaired, while the cholera vibrio tends to lose them.
3. Oysters from sources which appeared to be free from risk of sewage contamination exhibited none of the bacteria, specific or otherwise, which are commonly regarded as being concerned with sewage.
4. Oysters from a few out of numerous batches derived from sources where they did appear to be exposed to risk of sewage contamination were found to exhibit colon bacilli—a circumstance which, notwithstanding the comparative universality of this intestinal organism, may be regarded as having some significance by reason of the absence of this bacillus from oysters which appeared to have been exposed to no such risk.

Since that time there have been several considerable outbreaks of enteric fever and gastro-enteritis due to eating infected oysters, including two at Winchester and Southampton in 1902, which Bulstrode traced to eating oysters grown on beds polluted with sewage. He summarised the evidence as follows: Two mayoral banquets occur on the same

day in separate towns several miles apart. In connection with each banquet there occurs illness of analogous nature, attacking, approximately, the same percentage of guests (62 persons or 46·3 per cent. at Winchester, 55 persons or 41·3 per cent. at Southampton), and at corresponding intervals. At both banquets not every guest partook of oysters, but all those guests who suffered enteric fever, and approximately all those who suffered other illness, did partake of oysters. Oysters derived directly from the same source constituted the only article of food which was common to the guests attacked, and oysters from this source were at the same time and in other places proving themselves competent causes of enteric fever. Klein found *B. coli*, *B. enteritidis sporogenes*, and other organisms allied to the Gaertner group of bacilli in oysters from the same layings, and many other bacteriologists have demonstrated the presence of these organisms in oysters derived from polluted beds.

The results of the investigations carried out by Houston for the Royal Commission on Sewage tend to prove that the contamination of oysters by *B. coli* is widespread and not altogether dependent on sewage contamination. He examined over 1,000 oysters, and nearly all, from whatever laying they were taken, contained *B. coli* or coliform organisms. This did not hold good as regards deep-sea oysters, which were free from this organism (and spores of *B. enteritidis sporogenes*), as was also deep-sea water. Houston found the number of *B. coli* in an oyster varied from 10 to 10,000 (in 10–15 c.c.), and the contents of the stomach of the oyster contained more *B. coli* than the liquor in the shell. Fewer *B. coli* were found, as a rule, in oysters stored in pure waters, but instances occurred where the numbers of such bacilli were as great as in oysters from contam-

inated sources. It has been shown by various workers, most recently by Klein in 1905, that oysters, cockles and mussels have the power of clearing themselves of infective germs, partly by passing them out, and partly by "directly devitalising the microbe."

Such is some of the bacteriological evidence down to recent date, and whilst it may appear to be of a conflicting nature, there are certain conclusions which may be drawn. First, the number as well as the presence of *B. coli* in oysters must be considered. Secondly, topographical evidence as to pollution must be taken in conjunction with bacterial evidence, and, at present, the former is more reliable than the latter. Thirdly, oysters ordinarily grown on contaminated oyster-beds may, and do on occasion, contain the virulent specific bacillus of typhoid, which can live both in sea-water and within the shell of the oyster. This being so, the risk of typhoid infection from oysters is a real one, although in actual occurrence many conditions have to be fulfilled.

Preventive Measures.—Present legislation does not give to local authorities any power of inspection or control over oyster-layings or shell-fish beds, nor any powers to prevent the sale in their district of oysters and other molluscs derived from sewage-contaminated sources, nor have they powers to control the importation of foreign oysters from whatever source. Oysters fattened on contaminated beds should be deposited for a time in pure sea-water before consumption. They should on no account be stored in unclean water.

Other shell-fish than oysters from time to time cause epidemics or individual cases of gastro-intestinal irritation, and probably contain germs acquired from their food, which is frequently filth. In a report to the **L.G.B.** on "Cockles as Agents of Infectious Diseases," Klein recorded finding *B. coli* in 3 out of 8 cockles which had been taken from a

foreshore polluted with the discharge from a sewer outfall, and also *B. enteritidis sporogenes* in 4 of them. No typhoid bacilli were detected. In 8 raw cockles in their shells bought from a street hawker, he found no typhoid organisms, but *B. coli* was found in 5 out of the 8 cockles and *B. enteritidis sporogenes* in 4 out of the 8. In subsequent experiments Klein came to the conclusion that a mussel immersed for 22 hours in cholera-infected water retained the bacilli of cholera for 48 hours after immersion in clean sea-water, and the same may be said in respect of typhoid infection. Indeed, evidence was obtained showing that the typhoid bacillus could multiply in cockles. Merely pouring boiling water over a heap of shell-fish, as is customary, does not necessarily destroy either cholera or typhoid infection contained in them. Steam sterilisation or boiling is necessary. Since the time of Klein's report, a number of outbreaks of disease, including enteric fever, have been traced to the consumption of mussels and cockles, and it has been shown that the cooking which these shell-fish generally undergo is not sufficient to free them from risk.

Milk contains nitrogenous substances, fat, carbohydrates, salts, and water, and may be regarded, in a sense, as a complete diet in itself. The chemical composition varies somewhat according to the breed of animal, its age, the period since calving, and the diet and physical conditions.

	Average Country-fed Milk.	Average Town-fed Milk.	Alderney Milk.	Fore Milk.
Water . . .	88 %	86 %	87 %	90 %
Fat . . .	3	4	3·2	0·2
Proteid (Casein, etc.)	4	5	4·5	} 9·7
Milk Sugar . .	4·5	4·3	4·1	
Salts (Ash) .	0·7	0·7	0·7	0·7

Or the average milk constitution may be expressed thus:—

Fat	4·1	per cent.
Solids not fat . .	8·8	"
Total solids . .	12·9	"
Water . . .	87·1	"

Milks vary in standard, and the above figures can only be taken as fair averages.

Milk-sugar, or Lactose ($C_{12}H_{24}O_{12}$), is a constant constituent of milk, forms the chief substance in solution in whey or serum, and is a member of the cane-sugar group. Is found in varying quantities in the milk of mammals. About 5 per cent. is present in human milk; and somewhat less in that of the cow. It is very resistant to fermentation by yeast, and therefore undergoes alcoholic fermentation very slowly. It is not acted upon by rennet, pepsin, or trypsin. But of all the sugars it is most readily acted upon by micro-organisms.

Fat occurs in milk as suspended globules of varying size. It forms the cream, and by churning is, of course, made into butter, though both cream and butter contain other constituents besides fat. Lloyd has shown that it is the large globules that form the cream, and he has also made observations upon the size of fat globules in relation to breed of cattle. The decomposition and breaking down of milk-fat by fermentation is the chief cause of gross abnormalities of cream and the rancidity of butter. The proportion of cream averages about 8 per cent., but ranges from 6 per cent. in very poor milk to 12 per cent. or 15 per cent. or more; in Alderney cows it may reach 40 per cent. One part of cream is said to correspond roughly to 0·2 part of fat. More complete separation of cream is effected by centrifugalisation in a "separator." Skimmed milk retains as a rule about 1 per cent. or more of fat; separated milk much less. Both contain the casein, sugar, and salts of the milk from which they were made, and have therefore considerable nutritive value. "Fore-milk," which is the first part of the yield of milk from the udder, contains but little fat; the "strippings," on the other hand, at the end of milking, are rich in fat.

The Proteids of Milk include casein, lactalbumin, and lactoglobulin. Casein is the most abundant and important. When milk separates naturally into its constituent parts, the fat rises

and the casein falls, leaving a clear fluid, the milk plasma or serum, between the two substances.

Mineral Matter.—The ash of milk, obtained by careful ignition of the solids, contains calcium, magnesium, potassium, sodium, phosphoric acid, sulphuric acid, chlorine, and iron—phosphoric acid and lime being present in the largest amounts.

Human milk contains less fat, less proteid, and more sugar than cow's milk (*e.g.*, an analysis of average human milk would result in total solids, 12·5; fat, 3·7; proteids, 2·3; lactose, 6·2; and ash, 0·3), and therefore to modify cow's milk so as to bring it approximately to the standard of human milk, it is necessary to dilute it and add milk-sugar. Much debate has arisen as to what should be accepted as the minimum standard for the various constituents of milk. Broadly it is now usual to fix the fat standard at 2·75–3 per cent., and the "solids not fat" at 8·5 per cent.

The following are the recommendations (1901) of the majority of a Departmental Committee:—

1. That Regulations under s. 4 of the Food and Drugs Act, 1899, be made by the Board of Agriculture with respect to milk (including condensed milk) and cream.

2.—(*a*) That in the case of any milk (other than skimmed, separated, or condensed milk) the total milk solids in which, on being dried at 100° C., do not amount to 12 per cent., a presumption shall be raised, until the contrary is proved, that the milk is deficient in the normal constituents of genuine milk.

(*b*) That any milk (other than skimmed, separated, or condensed milk), the total milk solids in which are less than 12 per cent., and in which the amount of milk fat is less than 3·25 per cent., shall be deemed to be so deficient in milk fat as to raise a presumption that it has been mixed with separated milk or water, or that some portion of its normal content of milk fat has been removed. In calculating the percentage amount of deficiency of fat the analyst shall have regard to the above-named limit of 3·25 per cent. of milk fat.

(*c*) That any milk (other than skimmed, separated, or condensed milk) the total milk solids in which are less than 12 per cent., and in which the non fatty milk solids are less than 8·5 per cent., shall be deemed to be so deficient in normal constituents as to raise a presumption that it has been mixed

with water. In calculating the percentage amount of admixed water the analyst shall have regard to the above-named limit of 8·5 per cent. of non-fatty milk solids, and shall further take into account the extent to which the milk fat may exceed 3·25 per cent.

3.—That the artificial thickening of cream by any addition of gelatine or other substance shall raise a presumption that the cream is not genuine.

4.—That any skimmed or separated milk in which the total milk solids are less than 9 per cent. shall be deemed to be so deficient in normal constituents as to raise a presumption that it has been mixed with water.

5.—That any condensed milk (other than that labelled "machine-skimmed milk" or "skimmed milk," in conformity with s. 11 of the Food and Drugs Act, 1899) in which either the amount of milk fat is less than 10 per cent. or the amount of non-fatty milk solids is less than 25 per cent. shall be deemed to be so deficient in some of the normal constituents of milk as to raise a presumption that it is not genuine.

The following expressions of opinion are added:—

(*a*) That it is desirable to call the attention of those engaged in the administration of the Food and Drugs Acts to the necessity of adopting effective measures to prevent any addition of water, separated or condensed milk, or other extraneous matter, for the purpose of reducing the quality of genuine milk to any limits fixed by regulation of the Board of Agriculture.

(*b*) That it is desirable that steps should be taken with the view of identifying or "ear-marking" separated milk by the addition of some suitable and innocuous substance, and by the adoption of procedure similar to that provided by s. 7 of the Food and Drugs Act, 1899, in regard to margarine.

(*c*) That it is desirable that, so far as it may be found practicable, the procedure adopted in collecting, forwarding, and retaining, pending examination, samples of milk (including condensed milk) and cream under the Food and Drugs Acts should be uniform.

(*d*) That it is desirable that, so far as may be found practicable, the methods of analysis used in the examination of samples of milk (including condensed milk) or cream taken under the Food and Drugs Acts should be uniform.

(*e*) That it is desirable in the case of condensed milk (other than that labelled "machine-skimmed milk" or "skimmed milk," in conformity with s. 11 of the Food and Drugs Act, 1899) that the label should state the amount of dilution required to make the proportion of milk fat equal to that

found in uncondensed milk containing not less than 3·25 per cent. of milk fat.

(*f*) That it is desirable in the case of condensed whole milk to limit, and in the case of machine-skimmed milk to exclude, the use of sugar.

(*g*) That official standardising of the measuring vessels commercially used in the testing of milk is desirable.

The Sale of Milk Regulations of 1901 which followed this report lay down that (*a*) where a sample of milk contains less than 3 per cent. of milk-fat, it shall be presumed until the contrary is proved that the milk is not genuine by reason of the abstraction therefrom of milk fat or the addition thereto of water; (*b*) where a sample of milk contains less than 8·5 per cent. of "solids not fat," it shall be presumed until the contrary is proved that the milk is not genuine by reason of the abstraction therefrom of "solids not fat," or the addition thereto of water; and (*c*) when a sample of skimmed or separated milk (not being condensed milk) contains less than 9 per cent. of solids (including fat), it shall be presumed that the milk is not genuine. These regulations are in force throughout Great Britain.

Adulterations.—Addition of water and abstraction of cream are by far the most frequent frauds. Sodium carbonate, sodium chloride, starch, borax (1–2,000), formalin (1–50,000), or salicylic acid are occasionally added, either as preservatives or in order to mislead the analyst. Skimmed milk or separated milk is frequently fortified by the addition of condensed milk, and whole milk is not unfrequently diluted with separated milk. A good deal of "manipulation" of milk goes on, mixing of poor with rich, and of separated and condensed milks with water and with whole milk. Annatto and turmeric are often added to impart a yellow colour to milk.

Addition of water lowers the specific gravity, the

percentage of fat, "solids not fat," and salts; it also makes the cream rise more readily to the surface. Abstraction of fat, by skimming or by the use of the separator, increases the specific gravity and the percentage of salts and "solids not fat," but of course reduces the fat and therefore the yield of cream. The addition of condensed milk to skimmed milk may give an appearance of extreme richness, but the salts and "solids not fat" will be in excess.

Owing to the social changes by which an increasing percentage of the population lives in towns, the practice of adding preservatives to milk, with a view to "keeping" it over the necessary transit and delay in reaching the consumer, is increasing.

In 1901 another Departmental Committee appointed by the Board of Agriculture recommended:—

1. That the use of formaldehyde in food and drink be absolutely prohibited, and that salicylic acid be not used in greater proportion than one grain per pint or pound respectively for liquid or solid food, its presence in all cases to be declared.
2. That the use of any preservatives or colouring matter in milk be made an offence under the Sale of Food and Drugs Acts.
3. That boric acid preservatives only be allowed in cream the amount not to exceed 0·25 per cent. and be notified on a label.
4. That boric acid preservatives only be allowed in butter, the amount not to exceed 0·5 per cent.
5. That chemical preservatives be prohibited in all dietetic preparations for the use of children and invalids.
6. That the use of copper salts for "greening" be prohibited.
7. That a Court of Reference be established to supervise the use of preservatives and colouring matters in food.

Bacteria in milk.—Milk as it leaves the healthy udder is a sterile fluid, but at the time of milking, during transit to the dairy, at the milkshop, and in the home of the consumer, it becomes more or less contaminated. Being a favourable medium for the growth

of bacteria, and being frequently kept for some time at a favourable temperature for the multiplication of germs, milk becomes, as a rule, heavily impregnated with bacteria. Disease of the cow's udder when present would add a further quota. Thus it comes about that milk is often found to contain millions of bacteria per cubic centimetre, varying in number according to cleanliness or otherwise, treatment, temperature, and storage. The species of bacteria found in milk may be roughly classified as: (*a*) ordinary bacteria of soil and water; (*b*) bacteria of sewage, manure, or intestinal origin; (*c*) bacteria of fermentation, and (*d*) pathogenic organisms associated with tuberculosis, enteric fever, scarlet fever, diphtheria, sore throat and epidemic diarrhœa. Here it is only necessary to consider the last two groups of bacteria.

Milk sugar undergoes fermentation like other sugars upon the introduction of a suitable fermenting agent. There are five different kinds of such fermentation which affect milk, namely, lactic acid and butyric acid fermentations, coagulation fermentation without acid production, alcoholic fermentation, and, lastly, a group of anomalous changes of various kinds. *Lactic acid fermentation* is the ordinary souring of milk. The coagulated casein is precipitated, the serum rises and carries up lumps of fat, and the whole becomes acid. This change is due to a group of bacilli (*B. acidi lactici*), the first member of which was discovered by Pasteur and isolated by Lister. They gain access to milk from external sources, particular kinds being found in the vicinity of particular dairies, soils, geographical localities, etc., thus giving to milk and butter characteristic flavours.

The lactic fermentation bacteria are short rods, do not liquefy gelatine, nor do they form spores. They grow readily on gelatine at room temperature, forming as a rule small circular colonies, white or grey in

colour, with sometimes a tinge of yellow, and the surface of the colony is smooth and glistening. The lactic acid organisms produce appreciable amounts of lactic acid only at somewhat elevated temperatures. If the amount of acid rises much above 2 per cent., the growth of the lactic acid bacteria is inhibited. Many other substances are produced in addition to lactic acid (*e.g.* acetic and formic acids, alcohol, methane, CO_2, etc.). Only provisional classifications are possible at present, as, owing to variations in biology and terminology, it is probable that certain lactic organisms are described under several different terms. Generally, it may be said that some grow well in the presence of oxygen, and others do not. The most common members of the group are the facultative anærobes which sour milk best in deep vessels, and produce a right-handed lactic acid. They are widely distributed in nature, and may form 90 per cent. of the total bacteria in milk. Some produce gas, others liquefy gelatine, and some produce spores.

Butyric acid fermentation, due to the B. butyricus, is a bitter fermentation in which hydrogen and carbonic acid gas are produced. It has little of the importance of lactic fermentation or even of alcoholic fermentation by yeasts, by which "koumiss" is prepared from mare's milk and "kephir" from the milk of goats, sheep, and cows. Other fermentations of milk are represented in (*a*) bitter fermentations (due to Weigmann's bacillus or Conn's micrococcus); (*b*) slimy fermentations which produce the "ropiness" used in the manufacture of Edam cheese and tœttmœlk (due to *Micrococcus viscosus* and *Streptococcus hollandicus*, etc.); (*c*) soapy milk caused by *B. lactis saponacei*, and (*d*) a number of chromogenic fermentations.*

Pathogenic organisms gain access to milk both

* Red milk (*B. prodigiosus* and *B. lactis erythrogenes*); blue milk (*B. cyanogenes*); yellow milk (*B. synxanthus*); etc.

from the cow and from sources external to milk. The *tubercle bacillus* is the chief example of the former channel. Probably not less than 15 to 20 per cent. of the milch cows of this country are affected with tuberculosis, and about 2 per cent. with tuberculous disease of the udder.* The milk is most infective when the udder is diseased. From 1896 to 1903 it was found that 8·4 per cent. of the country milk brought into Liverpool was tuberculous, and percentages varying from 5 to 14 have been frequently reported in market milk in this country. Whilst tuberculosis is not commonly spread among human beings by means of an infected milk supply, there is evidence, derived from pathological and clinical experience, proving that tuberculous milk can and does on occasion set up some form of tuberculosis, human or bovine (*Raw*), in the bodies of man and other animals consuming the milk. Phthisical milkmen may introduce the human tubercle bacillus to milk. All danger may be obviated by boiling the milk. The *typhoid bacillus* has occasionally found its way from sewage, water, or infective dust into milk, which is a favourable medium for its multiplication. The same may be said of the *diphtheria bacillus*, which, in four cases on record, has been actually isolated from milk suspected of conveying the disease (*Bowhill, Eyre, Klein, Dean and Todd*). Some authorities now hold that diphtheria is a disease of the cow and that the bacillus sometimes gains access to milk from the udder. Various forms of streptococcus have also been isolated from milk. Their exact pathological significance is unknown.

Examination of Milk.

1 *Specific gravity* of milk is measured by a lactometer (which is a delicate hydrometer) or by a Westphal balance.

* There were 4,102,000 milch cows in the United Kingdom in 1901. A cow yields on an average about 400 gallons of milk per annum.

The specific gravity averages about 1030–1032. It is lowered by watering, and raised by abstraction of fat.

2. *Total Solids*, which range from 12 to 13 per cent., are estimated by evaporating a small quantity of the milk in a platinum dish, weighing before and after drying (weight of residue × 100 divided by weight of milk = percentage total solids). By deducting the amount of fat, the solids not fat are obtained. The ash of milk, usually about 0·7 per cent., is of little value as an indication of quality.

3. *Fat* may be determined (*a*) by mechanical methods such as centrifugalisation, or (*b*) by extraction of the fat by ether, with or without preliminary destruction of the caseine by acid. In Adams' method five c.c. of the milk are spotted on to a porous paper, which is thoroughly dried, and then rolled up and extracted with ether in a Soxhlet apparatus. The ether is syphoned off and evaporated, and when a constant weight is obtained the quantity of fat is determined. Bell's method is extraction of fat with ether, after evaporation of the whole sample, and this method is particularly useful in treating curdled milk.

The fat in unadulterated milk is never less than 3·0 per cent., unless the "fore milk" alone is taken, so that when skimming as well as watering is suspected, the ratio 3·0 : 8·5 may be taken as the minimum proportion of fat to "solids not fat," and if the "solids not fat" are x, the fat should be *at least* $\frac{3 \cdot 0}{8 \cdot 5}x$, and if the ascertained amount y of fat falls short of this, it is concluded that at least $100 \times \left(\frac{3 \cdot 0}{8 \cdot 5}x - y\right) \div \frac{3 \cdot 0}{8 \cdot 5}x$ per cent. of fat has been abstracted.

4. *Water*—The results of many thousands of analyses show that, although the fat varies greatly, the percentage of "solids not fat" in unadulterated milk falls below 8·5 very rarely. Hence 8·5 per cent. is adopted as a standard. If a given milk contains x per cent. "solids not fat," and x is less than 8·5, we can affirm that however poor the milk might have been originally, it must contain added water to the extent of at least $\left(\frac{8 \cdot 5 - x}{8 \cdot 5} \times 100\right)$ per cent. of the sample; or, in other words, it is $\left(\frac{8 \cdot 5 - x}{8 \cdot 5} \times 100\right)$ per cent. worse than genuine milk of poorest quality. If it was originally milk of fair quality, the adulteration must have been much greater.

5. *Preservatives in Milk.* — *Boracic acid* is detected by moistening the ash with alcohol and H_2SO_4, and applying a light to the mixture when so little as 1 part in 10,000 will give a green flame; or the ash may be treated with dilute HCl, and turmeric paper will be turned brown, and if touched with sodium carbonate, bluish-black. *Salicylic acid* is detected by curdling the milk with mercuric nitrate, and then, after shaking it up with ether, evaporating, and moistening the residue with ferric chloride. A blue coloration will denote the presence of salicylic acid. *Formalin*, if present, may be detected by the casein staining yellow on the addition of HCl.

6. *Bacteriological Examination* is somewhat similar to that of water. Plate cultivations are made, etc., but it is usually necessary to dilute the milk with sterile water. Special methods of examination have to be adopted in searching for pathogenic organisms. Generally it may be said that by the centrifuge or sedimentation flask the particulate matter is obtained, and 2 c.c. are inoculated into a susceptible animal. For reliable examination for the tubercle bacillus it is necessary to inoculate animals with the milk, as many bacilli simulate the tubercle bacillus in almost every particular, except its pathogenic effect. Special staining tests are necessary for *B. diphtheriæ* and anaërobic culture for *B. enteritidis sporogenes*. The number and kind of bacteria present should be determined, the degree of acidity, and the presence or absence of pus cells, yeast cells, dirt, etc.

Milk in relation to disease.—From the point of view of preventive medicine the most important milk-borne diseases are enteric fever, diphtheria, scarlet fever, sore throat illnesses, and epidemic diarrhœa. Tuberculosis is not commonly spread by milk, and only one or two outbreaks of milk-borne cholera are on record. Whether other infectious diseases, such as measles, whooping cough and small-pox, are ever conveyed by milk remains to be proved.

An inflammatory affection of the udder, known as *garget*, has been suspected of causing outbreaks of sore throat, etc., in those using the milk. Milk from cows suffering from foot-and-mouth disease is capable of producing illness with aphthous stomatitis, swelling of the tongue, and fœtor of the breath, especially

in children; in other cases a severe form of sore throat has been the chief feature. Similar symptoms may attend the consumption of milk from cows affected with inflammation or abscess of the udder. The evidence is less clear in regard to other specific diseases to which cows are subject, and, indeed, in most of them the secretion is suppressed, but the milk should never be used for food. In the Western States of America cows are subject to a disease called the "trembles," supposed to be due to their eating *Rhus toxicodendron*, and their milk appears to cause in children vomiting, constipation, swelling of the tongue, and prostration, with abnormally low temperature. The milk of goats that had fed on *Euphorbium* or Meadow Saffron has been known to induce severe diarrhœa. Even in the human subject bitter and purgative drugs, not to mention morphia and other alkaloids, if taken by the mother, act upon the infant through the milk. Colostrum, the milk yielded by cows immediately after calving, has also been shown to exert a deleterious effect on persons consuming it. Lastly, disease has been caused, it is believed, by yeast cells in milk. Such an outbreak occurred at Lincoln in 1902 (199 cases). The symptoms of the disease simulated scarlet fever. There was much swelling of the tonsils and cervical glands with pyrexia, gastritis, and "rheumatism." Klein isolated what he believes to be a pathogenic yeast possibly bearing a relationship to the spores of rusts, smuts, and mushroom fungi consumed by the cows yielding the milk.

Enteric Fever.—In 1857 Michael Taylor, of Penrith, first established the fact that milk may convey enteric fever. Since that date more than 150 epidemics of this disease have been traced to an infected milk supply. Schuder states that 17 per cent. of all typhoid epidemics are thus caused. The channels of infection

by which the bacillus obtains access to milk have been shown by a study of these outbreaks to be from direct contact with typhoid patients, from washing milk vessels with infected water, from the addition of such water to the milk, from the air by dried typhoid excreta, from contaminated cloths and clothes, and from cooling milk in infected water.

Diphtheria.—The first epidemic of diphtheria which was shown to be milk-borne was one in North London in 1878, elucidated by Power. More than 30 similarly caused outbreaks of the disease have since been recorded. How the diphtheria bacillus gains access to milk is not known, but in all probability it is generally by direct contact. Persons suffering from the disease may remain for a long period infectious by reason of the retention for weeks after convalescence of the bacillus in the throat. Materials may also retain the infection for long periods. Water and sewage do not appear to convey the diphtheria bacillus. Klein holds that the Klebs-Löffler bacillus is inoculable in cows, producing a specific eruption on the udder, and within five days the bacillus is excreted in the cow's milk. Several outbreaks of diphtheria have suggested that bovine diphtheria is transmissible to man by milk.

Scarlet Fever.—More than 70 milk-borne attacks of scarlet fever are on record, and yet comparatively little is known either of the bacteriology of the disease or of the mode of infection of milk. Direct contact of scarlet fever patients with the milk trade is the most obvious channel of infection. In 1882 Power found reason to suspect that cows suffered from a disease which could impart to milk the virus of scarlet fever, and in 1885 in the "Hendon disease" outbreak further evidence of this was met with.

In that year a sudden and extensive outbreak of scarlet fever occurred in Marylebone, and was found to be associated with a

particular milk supply derived from a farm at Hendon. The milk was also distributed in St. Pancras, Hampstead, Hendon, and St. John's Wood; in each of these districts, except the last, scarlet fever suddenly became prevalent early in December. On the 15th the milk sent to Marylebone was returned to the farmer, and some of this was given away to persons at Hendon on the 15th and 16th; a few days later, from December 20th onwards, a number of cases of scarlet fever occurred among those who had drunk the milk, and at the same time there was a sudden decrease in the number of attacks in Marylebone. The disease was conveyed by the milk, and after close investigation Power and Klein were led to the important conclusion that the cow itself was the source of infection.

There had been apparently no case of scarlet fever among the employés that could be proved to have infected the milk. Attention was next directed to the cows, and many of them were found to be suffering, or to have recently suffered, from vesicles or ulcers upon the teats and udder. These were clearly infectious, and had been first seen upon a cow that was bought on November 15th. The dates of outbreak of scarlet fever in each district being known, it was found that each outbreak was preceded by a few days by the introduction of this affection into the cowsheds from which the milk supply of the district was drawn. The early exemption of St. John's Wood was explained by the fact that the disease had not appeared in the small shed from which alone its supply was drawn; but during the inquiry this shed became affected at last, and an outbreak in St. John's Wood immediately followed. All the cows showing any signs of the disease were then isolated, and no further cases of scarlet fever occurred among the consumers of the milk. The symptoms noticed in the cow were chiefly local, but there were bald patches of skin, especially about the tail and back, the epidermis in these patches being scaly and the cutis thickened. There was no pyrexia. The vesicles, which were small, were confined to the teats and udder. They extended, and in two days formed flat irregular ulcers covered with brown scabs. Inoculated upon calves, the matter from these ulcers caused local tenderness and swelling in three days, a scabbed ulcer with vesicular margin in six days, and a further extension during the next few days, followed by healing. By cultivation a streptococcus was obtained, supposed to be identical with a similar organism found by Klein in connection with scarlet fever, and having the property of solidifying milk if kept for two days at 35° C. was not found in the milk from unaffected teats. Inocula-
of calves with pure cultivations of the streptococcus pro-

duced a constitutional disease that had some points of analogy with scarlet fever, the condition of the kidneys especially differing but little from acute scarlatinal nephritis.

Sore-throat illnesses.—Somewhat allied to scarlet fever, and possibly in some instances an aberrant form of that disease, is sore-throat infection conveyed by milk. There are fully a score of well-marked epidemics of this nature on record. One of the first to be investigated occurred in South Kensington in 1875. About 150 persons were affected after consuming cream. A similar outbreak occurred in Edinburgh in 1888. More recent outbreaks of milk-borne sore-throat occurred at Bedford in 1902, Woking 1903, Finchley 1904, and Colchester 1905. Cream was again the particular medium at Bedford, where the incidence was chiefly upon young adults. At Woking 98 families were affected, and the milk was traced to cows suffering from *suppurative mammitis.* The Finchley outbreak involved 500 cases. The incubation period, as in many of these sore-throat conditions, was short—24 to 48 hours. There was enlargement of the submaxillary glands, sore-throat, fever, general malaise, and in a few cases a measles-like eruption on the lower limbs. On some occasions gastro-intestinal irritation has also been present. It is possible that these sore-throat illnesses are of streptococcal origin.

In many milk-borne outbreaks of scarlet fever there occur a number of sore-throat cases simulating, but possibly not identical with, scarlet fever, in addition to those which are milder forms of scarlet fever itself.

Epidemic diarrhœa is another infective disease which appears to be conveyed by milk. Certain attacks of the disease give support to this view, and there is also the autumnal rise of infantile diarrhœa, which is

attributed by many observers, in part, to contaminated milk. It is held that the high atmospheric temperature of the third quarter of the year exerts a prejudicial effect on milk, causing it to be injurious, particularly to infants and children. It is certain that breast-fed infants suffer much less than artificially fed infants from such disease. Actual epidemics of milk-borne diarrhœa have been, it appears, comparatively few. In 1894 such an outbreak occurred in Manchester, affecting 160 persons, and due probably to milk polluted with excreta ; and in 1895 and 1898 three outbreaks occurred at St. Bartholomew's Hospital, traced to the consumption of milk or milk-pudding from which Klein isolated the *B. enteritidis sporogenes*, which he regards as the *vera causa* of epidemic diarrhœa.

Characteristics of milk-borne epidemics.—There are certain general characteristics of outbreaks of disease transmitted by milk which it may be well briefly to state here.

1. The outbreak is usually sudden in onset; and the cessation often almost equally so, if allowance is made for late cases in infected households, which have probably been infected from the earlier cases and not by the milk.

2. A large proportion of the attacks are simultaneous or nearly so. The outbreak reaches its maximum too rapidly to admit of satisfactory explanation by the hypothesis of infection from the first cases ; thus, in an outbreak of scarlet fever at Wimbledon in 1886–7, the daily number of attacks was as follows :—

Date .	Dec. 25	26	27	28	29	30	31	Jan. 1	2	3
Attacks .	1	11	39	53	75	118	65	86	25	15

3. It will often happen that two or more persons in the same household are taken ill at the same

time. Such multiple cases may also occur apart from milk or water infection, but it is very exceptional, especially as regards the first invasion of the household.

4. The average number of cases per infected household is usually greater than occurs under ordinary conditions, but this is of course dependent upon the number of persons who consume the milk. An *average* of two attacks per household may be considered high.

5. A large proportion of the households attacked have a common milk supply, which, however, may not be distributed by the same retailer.

6. Conversely, if (*a*) the number of households supplied by the suspected dairy be ascertained, and also (*b*) the number of such households attacked, it will be found that the proportion of (*b*) to (*a*) is much greater than the proportion which the total number of infected households bears to the total number of inhabited houses in the district. Although in some cases 50 per cent. or more of the houses supplied with the implicated milk are attacked, in other instances the proportion is far lower.

7. If the households supplied by the dairy in question are classified according to the quantity of milk bought daily, the invasions are found to be proportionately more numerous among households taking a larger supply.

8. A similar calculation, substituting individuals for households, will give similar results. Classifying the consumers according to the average consumption per head in the households to which they belong, a heavier incidence upon the larger consumers will be manifest. Hence the wealthier consumers, upon the average, suffer more than the poorer class in milk-borne outbreaks, and a classification according to rental will usually confirm this.

The Wimbledon outbreak, already referred to, illustrates these relations (*Cooper*) :—

Incidence on Consumers, according to Supply per Head.		Incidence on Houses, according to Supply per House.		Incidence on Houses, according to Rental.	
Pints.	Percentage of Persons supplied attacked.	Pints.	Percentage of Houses supplied invaded.	Rateable Value of Houses supplied.	Percentage of Houses supplied invaded.
·05 to ·1	14	·25	40	£10 to £12	21
·1 to ·2	23	·5	40	£13 to £15	39
·2 to ·3	41	·75	50	£16 to £20	50
·3 to ·4	39	1·0	49	£21 to £25	64
·4 to ·5	46	1·5	58	£26 to £30	66
·5 to ·6	57	2·0	70	£31 to £35	57
·6 to ·7	40	3·0	67	£36 to £40	76
·7 to ·8	46	3·5	74	£41 to £50	73
Over ·8	49	Over 3·5	78	£51 to £60	74
				£61 upwards	80

9. Among persons who drink little or no milk, or only take it in tea or coffee, or always have it boiled, attacks will be rare, except after exposure to infection from earlier cases.

10. As a corollary to this, there is often a much heavier incidence among children and women than among men. This would be especially significant in regard to enteric fever, which under ordinary conditions chiefly affects adults. On the other hand, Littlejohn has pointed out that in milk-borne scarlet fever an exceptionally high proportion of adults may suffer.

11. The type of disease in milk-borne epidemics has

been noticed to be, as a rule, mild, and attended with low mortality.

12. The incubation period is shortened, and there is some reason to suppose that the degree of infectiousness by contact is lower than when such diseases are not milk-borne.

Ice-cream or iced custards which have as their basis milk or cream mixed with other ingredients, may be briefly considered here in their relation to infection. A number of outbreaks of typhoid or diarrhœal disease have been attributed to the consumption of ice-cream. Such outbreaks occurred at Deptford in 1891, Liverpool 1897, City of London and Finsbury 1902, and Paisley 1904. The ice cream may become infected owing to storage in infected premises, between the process of "boiling" and that of "freezing," or owing to the fact that the substance has been made by a person suffering from recognised or unrecognised disease. It is on this account that, since 1895, local regulations have been in force with a view to controlling the manufacture of ice-cream. Some of the most recent of such regulations are contained in the London County Council (General Powers) Act, 1902, under which ice-cream must be made and stored in sanitary premises, not living rooms, precautions must be taken as to protection from contamination, and the name and address of the maker must appear on the street-barrows. Similar powers are conferred by local Acts in Liverpool, Glasgow, etc.

Control of Milk Supplies.—The requirement is a pure milk supply, or in other words a clean, whole milk, unsophisticated and unadulterated, (*a*) derived from healthy cows, guaranteed free from tuberculosis by the tuberculin test, and living under clean and sanitary conditions; (*b*) obtained by clean methods of milking, strained, and protected from contamination and from infection; (*c*) kept cool by means of refrigeration, and (*d*) not exposed to dust or uncleanliness in any way from the vessel in which it is placed, or from the persons by whom it is handled.

Low temperatures do not readily destroy germ life,

but they have a most beneficial effect upon the keeping quality of milk. If the temperature be lowered sufficiently, the contained bacteria become inactive and torpid, and eventually are unable to multiply or produce their characteristic fermentations. At about 50° F. (10° C.) the activity ceases, and at a temperature of about 40° F. organisms are practically deprived of their injurious powers. If the milk is to be conveyed long distances, then even a lower temperature is desirable. The most important point with regard to the cooling of milk is that it should take place *immediately*. Various kinds of apparatus are effective in accomplishing this. Perhaps those best known are Lawrence's cooler and Pfeiffer's cooler, the advantage of the latter being that during the process the milk is not exposed to the air. It must not be forgotten that cooling processes are not sterilising processes, and do not necessarily kill bacteria; they only inhibit activity, and under favourable circumstances torpid pathogenic bacteria may again acquire their injurious faculties. Hence, during the cooling of milk even greater care must be taken to prevent aërial contamination than is necessary during the process of sterilising milk. No cooling whatever should be attempted in the cowshed. Climate makes little or no difference to the practical desirability of cooling milk, yet it is obvious that less cooling will be required in the cold season. The further treatment of milk has in practice comprised the addition of *preservatives*, *filtration*, and *sterilisation*, but with first-rate clean milk, consumed or bottled immediately after yield, these are not necessary.

Preservation of milk may be effected by boiling, by exclusion of air, or by the addition of sugar, borax (1–2,000), formalin (1–50,000), or other antiseptic. Such preservatives are frequently added to milk, especially in towns. They prevent rapid

multiplication of germs, and so delay or prevent fermentation. On the other hand, they disguise the true condition of the milk, and by cumulative process may cause poisoning in the consumers, and therefore should be condemned. *Condensed milk* is prepared by evaporating down *in vacuo* at a low temperature to about one-third or one-quarter of the original volume, and most manufacturers then add cane sugar as a preservative. The added sugar renders it too carbonaceous and "fattening," though lacking in fat, but apart from this the nutritive value of condensed milk seems to be inferior to that of fresh milk, especially in regard to bone-formation and stamina. Condensed milk is, as a rule, fairly free from suspicion of ordinary adulteration or pollution, but in one instance it was believed to be the means of spreading scarlet fever. Such milks are by no means always sterile.

Filtration of milk has also been recommended, and is practised in Denmark, but is little adopted in this country.

Sterilisation means the use of heat at or above boiling-point, or boiling under pressure. This may be applied in one spell of one to two hours at 212–250° F., or at stated intervals at a lower temperature. The milk is sterilised—that is to say, contains no living germs—is altered in chemical composition, and possesses a flavour which to many people is unpalatable.

Such a radical alteration is not necessary in order to secure non-infective milk. The bacteria causing the diseases conveyable by milk succumb at much lower temperatures than the boiling-point. Advantage is taken of this in the process known as *pasteurisation* in which milk is heated to 167–185° F. (75–85° C.). Such a *temperature* kills harmful microbes, because *75° C. is above their* average thermal death-point and

yet the physical changes in the milk are practically *nil*, because 85° C. does not relatively approach the boiling-point. There is no fixed standard for pasteurisation, except that it must be above the thermal death-point, and below the boiling-point. As a matter of fact, 158° F. (70° C.) will kill lactic acid bacteria and most disease-producing organisms found in milk. If milk is kept at that temperature for ten or fifteen minutes it has been "pasteurised." If it has been boiled, with or without pressure, for half an hour, it has been "sterilised." The only practical difference in the result is that sterilised milks have a better keeping quality than pasteurised, for the simple reason that in the latter some living germs have been unaffected.

Sterilisation may, of course, be carried out in a variety of modifications of the two chief ways above named. When the process is to be completed in one event an *autoclave* is used, in order to obtain increased pressure and a higher temperature. Milk so treated is physically changed in greater degree than in the slower process. The slow or *intermittent* method is, of course, based on Tyndall's discovery, that actively growing bacteria are more easily killed than their spores. The first sterilisation kills the bacteria, but leaves their spores. By the time of the second application the spores have developed into bacteria, which in turn are killed before they can sporulate.

The application of pasteurisation to milk is now very widely adopted by corporations, dairy companies, hospitals, milk-dispensaries, etc.

Butter.—When cream is violently agitated, the fat globules are ruptured and their contents clot together as butter. The water is expelled by pressure, and salt is added. The flavour of butter is due to the butyrin, caproin, and caprylin, which together constitute about 7·8 per cent. of the fat, the

rest being composed of olein, stearin, and palmitin. Besides fat, which constitutes about 85 per cent., butter contains water, casein, and salts. The casein averages 2·5 per cent., but may reach 7 per cent. if the butter is carelessly made; such a butter keeps badly. The water ranges from 8 to 12 per cent. in good butter, and should never exceed 16 per cent. "Milk-blended" butters have been found to contain nearly double this amount of water. The ash should not exceed 8 per cent.; in pure fresh butter it is usually about 2 or 3 per cent. or less, and includes calcium phosphate and sodium chloride.

Adulterations and Analysis.—The addition of annatto or other harmless colouring matter is not regarded as adulteration. Starch is sometimes added, and may be recognised by its blue reaction with iodine. The chief and only important adulterations practised are the substitution of foreign fat and the addition of water, and, therefore, the analysis of butter turns chiefly upon the proportion and composition of the fat and the proportion of water.

1. The fat should exceed 80 per cent. of the whole. (If the butter is melted in a tall glass, the water and curd will collect at the bottom, leaving the pure fat above.)

2. The specific gravity of pure butter fat should range from 911 to 913. Margarine examined under similar conditions would range from 901 to 906.

3. The melting-point of the fat should be about 35·8° C., but it is liable to variation, not only with variation in the relative proportions of normal constituent fats, but also with repeated meltings. Adulteration with dripping, lard, or other animal fat raises the melting-point, while vegetable fats lower it.

4. The soluble fatty acids (butyric, caproic, caprylic) should not be less than 5 per cent. of the fat, and the insoluble fatty acids should not exceed

89·5 per cent. Butter fat differs from all others in containing fatty acids that are soluble in water, and their partial or complete absence denotes substitution of foreign fat.

5. Pure butter fat is readily soluble in ether, whereas other fats dissolve slowly and leave a residue.

6. Fat crystals may be visible under the microscope, and serve to show that the butter has been melted, presumably for the purpose of adulteration.

7. Water is estimated by heating a weighed quantity of butter over a water-bath until it ceases to lose weight.

The Regulations for the sale of butter, made in 1902 by the Board of Agriculture under section 4 of the Sale of Food and Drugs Act, 1899, provide that, "Where the proportion of water in a sample of butter exceeds 16 per cent. it shall be presumed for the purposes of the Sale of Food and Drugs Acts, 1875 to 1899, until the contrary is proved, that the butter is not genuine by reason of the excessive amount of water therein."

Nothing has been made out very clearly as to the convection of specific disease by means of butter. An outbreak of diarrhœa in a large hospital was shown by Shirley Murphy to be in all probability due to the consumption of a particular kind of butter. The symptoms resembled those of tyro-toxicon poisoning, to be mentioned presently.

Margarine has been the subject of special legislation (the Margarine Act, 1887, and the Sale of Food and Drugs Act, 1899), which will be referred to in another section. The term is applied generically to fats, for the most part of animal origin, prepared by churning melted and clarified beef or mutton fat with skim milk, and so treating it as to resemble *butter in appearance* and flavour as far as possible. *For this purpose* a certain proportion of genuine

butter is frequently mixed with it. It may possess nutritive value little inferior to butter, especially if manufactured from pure animal fats. Chemically it differs from butter in containing only traces of "soluble" fatty acids. It consists mainly of olein, stearin, and palmitin. The absence of butyrin, a chief constituent of butter fat, is the most valuable means of distinguishing between butter and margarine.

Cheese is formed by the action of rennet upon milk, and consists of coagulated casein with a variable proportion of fat and salts. The best, such as Cheddar, Cheshire, double Gloucester, and most American cheeses, are made from entire milk, the poorer from skim milk, or a mixture of skim and entire milk. Stilton cheese is made from entire milk to which cream has been added. Cheeses vary widely as to the amount of fat and water which they contain. A good cheese, if kept under suitable conditions of temperature, undergoes a change, known as "ripening," which improves its flavour. Oxygen is absorbed, ammonia and carbonic acid are given off. The casein undergoes fatty metamorphosis, and the calcium phosphate reacts upon the fats and the casein, giving rise to lime salts of fatty acids, and a soluble compound of casein with phosphoric acid. Lactic acid, valerianic acid, and leucin are also formed. Both in cheese and butter-making this ripening process is due to bacteria and their products, and it is on account of this fact that much has been done in Denmark and America in the way of flavouring butter and cheese by introducing favourable organisms as "starters" of the desired fermentation. Both natural and artificial ripening occasionally go wrong, and as a result we get abnormalities, such as rancid butter, "gassy" cheese, coloured cheese, or *bitter cheese*. Occasionally also poisonous bodies, *such as tyro-toxicon*, result.

Tyro-toxicon (diazo-benzene butyrate) is a poison discovered by Vaughan in cheese that has undergone a peculiar fermentation. Such cheese is not necessarily altered in appearance or taste, but has a much stronger acid reaction than usual. Tyro-toxicon can be detected chemically by neutralising with sodium carbonate, exhausting with ether, evaporating the ethereal solution, and dissolving the residue in water. The aqueous solution strikes an orange, red, or purple colour when treated with a mixture of equal parts of carbolic and sulphuric acids. It is unstable, and present generally in only very small quantities, which are difficult of detection. It is intensely poisonous, causing dryness of the mouth and fauces, a sense of constriction in the throat, nausea, vomiting, diarrhœa, and great nervous prostration. The symptoms usually pass off in a few hours, but may end in death from collapse. Butter and cream, as well as cheese, have given rise to tyro-toxicon poisoning. In 1883–84 there occurred in Michigan, U.S.A., an outbreak of cheese poisoning, which affected 300 persons, due to tyro-toxicon (Vaughan), and in 1901 seventeen cases of tyro-toxicon poisoning occurred in Finsbury. In both outbreaks the incubation period was short (only a few hours), and the symptoms were as stated above.

Adulterations of cheese are unimportant. Starch is said to be added sometimes. The use of skimmed milk or colouring matter is not regarded as adulteration. Cotton-seed oil or other foreign fat is sometimes added in place of the abstracted cream (margarine cheese).

Analysis.—The proportion of fat to casein should not be less than 1 to 2 at the very lowest; sometimes the fat exceeds the casein. The fat may be extracted with ether, or mechanically by the Leffmann-Beam process of melting and centrifuging. The fat should be examined by the Reichert method. Water ranges

from 20 to 35 per cent., fat from 35 per cent. down to 22 per cent. in good cheese, and to 1 per cent. in skimmed milk cheese. Casein varies between 25 and 50 per cent., and salts between 3 and 6 per cent.

Lard, which is the internal fat of the abdomen of the pig, should be absolutely free from water and from foreign fat. The addition of water, which is not now widely practised, is detected by melting the lard in a tall glass and allowing time for the water to collect at the bottom. Cotton-seed oil is the other important adulterant. It is detected by its low melting-point, high power of absorbing iodine, and reduction of nitrate of silver.

Eggs.—The average weight of a hen's egg is about 2 oz., of which 10 per cent. is shell, 60 per cent. white, and 30 per cent. yolk. The white consists of albumen, with 86 per cent. water, and the yolk of albumen and fat with 52 per cent. water. The percentage composition may also be stated thus :—Shell 10 per cent., albumen and fat 23 per cent., water 67 per cent.

Preservation.—Air may be excluded by coating the shell with butter, lard, oil, wax, gum, etc., or by boiling for half a minute so as to coagulate the surface albumen. Antiseptics are also employed, *e.g.* the eggs are immersed in lime water, salt water, or solution of boro-glyceride.

Tests are only necessary for the detection of stale or rotten eggs. Two ounces of salt in a pint of water forms a solution in which good eggs sink and stale ones float. Fresh eggs are transparent at the centre, stale eggs at the top.

Vegetable Foods.

Wheat-flour is rich in albumen and carbohydrates, poor in fat and salts of organic acids. It contains 8 to 12 per cent. of gluten, and can

therefore be made into bread. The salts are chiefly phosphates of potash and magnesia.

Examination of Flour.—Flour should be free from acidity or mouldy smell. The colour should be white, a yellow colour indicates age, fermentation, or conversion of starch into dextrin and sugar.

The microscope may reveal any of the following :—

(1) *Foreign starches*, especially potato and rice, the characters of which will be described presently. (2) *Fungi*, the most common of which are sporangia of *Puccinia.* One species of *Puccinia* produces "caries" or "smut" of wheat; smut gives the flour a disagreeable smell, and the bread a blue colour. It is said to cause diarrhœa. (3) *Vibriones* and other organisms in fermenting flour. (4) *Acarus farinæ*, common in damp, inferior flour which is beginning to change. *Weevils* (*Calandra granaria*) can also be seen with the naked eye.

Adulterations and impurities.—The chief are the addition of foreign starches and mineral matters.

ANALYSIS.—*Water* should not exceed 16 per cent. The more the water the greater the liability to change. *Gluten* should not be less than 8 per cent., and may reach 12 per cent. It is separated by making the flour into a paste and working it with the fingers in a stream of water until all the starch is washed away. *Ash* should not be less than 0·8 per cent., or more than 2 per cent. If excessive, it should be tested for iron (indicating addition of clay), calcium sulphate, and magnesium carbonate. A simple test is to shake the flour with chloroform ; the flour floats, but mineral matters sink. *Alum* is sometimes added during grinding.

Ergotised flour is detected by making it into a paste with dilute alkali, adding slight excess of dilute nitric acid, and then neutralising; ergot gives a reddish violet colour, changing to red in presence of nitric acid, and to violet in presence of alkali. Potash gives a herring-like smell with ergotised flour.

Foreign starches will be recognised under the microscope, but a few other tests are available. Bean meal gives off a characteristic smell when drenched with hot water, and may also be detected by the successive addition of nitric acid and ammonia, which strikes a deep red colour. Potato starch grains swell up on the addition of a trace of potash in solution, which scarcely affects wheat starch grains. Pure wheat flour, made into a dilute solution in water, is turned pink on addition of iodine; but if any potato starch is present, a dark purple colour will appear.

The flour should also be put to the practical test of bread-making.

Bread is made by mixing flour with water, and kneading it, so as to form dough by the cohesion of the moistened gluten. The dough is charged with carbonic acid, which occupies innumerable lacunæ and renders the mass porous. It is then baked and becomes bread. The carbonic acid is supplied by the use of yeast ("leaven") or baking-powders (dry alkaline carbonates mixed with tartaric or other acid), or by kneading the dough with water charged with carbonic acid gas under pressure ("aërated" bread). 100 lbs. of flour make about 130 to 150 lbs. of bread.

During baking a certain proportion of dextrin and sugar is formed from starch, and there are traces of lactic and butyric acid. Alum checks these changes, which are especially prone to occur if bad flour is used. Mechanically aërated bread is the whitest and most free from dextrin and sugar. About 1 per cent. of boiled potato is frequently added to the dough.

Examination.—Bread should be white. A yellow or dark tint may be due to old or inferior flour, bad yeast, admixture of rye, or merely to presence of bran. Acidity may be caused by old or inferior flour. Bread is heavy and sodden if from any cause the dough has not risen sufficiently; such causes are bad yeast, bad flour, too much or too little heat, or defects in manipulation.

Water should not exceed 45 per cent. An excess lowers the nutritive value, and favours the growth of fungi. The *ash* ranges from 1·3 to 2·0 per cent. *Alum* is detected by pouring upon a slice of bread, moistened by water, a freshly made decoction of logwood chips, and then a solution of ammonium carbonate. If alum is present it acts as a mordant, and after the lapse of half-an-hour, or less, a strong blue colour is manifest, which is quite distinctive for practical purposes, so far as bread analysis is concerned, although magnesium carbonate would, if present, give the same reaction. Pure bread is merely stained pink by the reagents, and on drying this changes to a dirty brown. The blue given by alumina salts is permanent on drying—much more so than in the magnesium carbonate reaction.

For legal purposes it is necessary to determine the alumina quantitatively, and then a deduction must be made for the maximum amount of phosphate of alumina which may be present in pure bread. It is usual to deduct 16 grains (of alum) per 4-lb. loaf, anything in excess of this being regarded as adulteration. In exceptional cases pure flours may contain more than this, and many analysts now allow 8 or 10 grains per 4 lbs. Alum used for purposes of adulteration usually amounts to from 20 to 40 grains per 4-lb. loaf.

Foreign starches, especially rice and potato starch, may sometimes be detected under the microscope even after baking, but as a rule they are beyond recognition in bread. Potato makes the bread damp; the percentage of water is high, and the ash is alkaline instead of being neutral. Rice has in itself a low ash (0·85) per cent. Excessive moisture and low ash should raise suspicion of foreign flour. High ash, on the other hand, is suggestive of mineral adulteration.

The seeds of *Lolium temulentum* (darnel grass) may occasionally be ground with wheat flour, and cause vertigo, vomiting, convulsions, and other symptoms of poisoning. Various fermentations also occur in bread, producing chromogenic changes, bitter, slimy, or mouldy bread.

Barley is in the main similar to wheat in chemical composition, but contains more nitrogen, iron, and phosphates. It is liable to cause diarrhœa. Actinomycosis is now regarded as due to eating raw barley or other cereals, upon which the *actinomyces* is epiphytic. **Oats** contain more fat and more nitrogen than wheat, and are more readily cooked, but gluten is wanting, and hence bread cannot be made of oatmeal.

Rye contains less gluten than wheat, and makes a dark sour bread, which is apt to cause diarrhœa in those unaccustomed to its use. Ergotism results from the use of rye attacked by *Claviceps purpurea.* **Maize** (Indian meal) contains much fat, and its albumen to be made digestible requires careful cooking. Pellagra has been attributed to a fungus (*verdet*) attacking maize. **Rice** is poor in nitrogen, fat, and salts, but is very digestible.

Leguminosæ contain much nitrogen, chiefly in the form of legumin. Peas and beans are less digestible than cereals, and require prolonged gentle boiling.

Watercress grown or washed in polluted water was found to be responsible for an outbreak of enteric fever in Hackney in 1903, which shows that inspection of watercress beds is necessary. Intestinal parasites may also be derived from the same source.

Potatoes are antiscorbutic and very digestible. Good potatoes sink in a saline solution of specific gravity 1,100; bad ones float.

Starch is not a simple chemical substance, but a mixture of three bodies—*granulose*, *erythro-granulose*, and *cellulose*, which are respectively turned blue, red, and yellow by iodine. Granulose is the most important of these. Boiled in water, or with oxalic or other organic acid, it is converted into "soluble starch" or *amidulin*, a soluble dextro-rotatory substance chemically indistinguishable from granulose, and giving the blue iodine reaction. If instead of organic acid a 2 per cent. solution of sulphuric acid is boiled with the granulose or starch, the soluble starch first formed is converted into *dextrin* or *erythro-dextrin*, a sort of gum, which is dextro-rotatory, and is reddened by iodine; it is precipitated by alcohol and acetic acid, but not by tannic acid. Still further heating with sulphuric acid produces *achroödextrin*, which gives no colour reaction with iodine, and *glucose*.

Erythro-granulose is present in small proportion in wheat starch, and almost absent in potato. Its affinity for iodine is greater than that of granulose, but the red tint is completely hidden by the deep blue of the iodine-granulose. If a minimal proportion of iodine is employed, the red colour appears. Both the red and blue disappear on heating, owing to dissociation of iodine and starch, but reappear on cooling.

Starch occurs in the various farinacea in microscopic granules, which in many cases have a sufficiently characteristic appearance to indicate their origin. The granules vary greatly in size. Some are roundish, others oval, pyriform, truncated, polyhedral; some have distinctive markings, especially faint concentric rings or a hilum.

Microscopic examination of starches.—A little of the starch, *in a state of fine powder*, should be mixed with a drop of water,

During germination, the insoluble starch is converted into dextrine, maltose and glucose, the process being completed by "mashing" with water at 160° F. The wort is then boiled, hops are added, and after cooling, the liquid is discharged with yeast into the fermenting tun. Non-malt beers are made by fermenting glucose and allied substances obtained by the action of sulphuric acid upon starch. Wines are produced by fermentation of the juice of the grape, complete fermentation resulting in a dry wine, incomplete in an effervescing or sparkling wine. Spirits are prepared by the distillation of some previously fermented liquor; brandy from wine, whisky from malted barley, rum from molasses. But there are many varieties in distillery methods, and much "brandy" is made from potato spirit.

From the point of view of the medical officer of health alcoholic beverages assume importance in three ways: (1) disease caused by excessive consumption; (2) adulteration, and (3) fraudulent imitations sold to the prejudice or injury of the purchaser.

The diseases commonly attributed to excessive consumption of alcohol are chiefly alimentary or nervous, producing cirrhosis of the liver and various forms of gastric disease, or alcoholic neuritis, delirium tremens, etc. There is, of course, in addition, a large amount of disease, directly or indirectly, due to alcoholism, which does not appear in death certification.

Arsenic in Beer.—Of adulterants introduced accidentally or otherwise into alcoholic beverages, arsenic in beer is perhaps the best example. In 1900 there was wide prevalence of illness in South Lancashire and elsewhere, which was, after a time, identified by Reynolds as a form of arsenical poisoning, and traced to the consumption of beer from certain breweries in which highly arsenical brewing sugars had been used. These were found to be derived from a common

supply, in the manufacture of which, from starch, arsenical sulphuric acid had been used. The arsenic (As_2O_3) found in the sulphuric acid was 1·9 per cent., in the artificial sugars 0·008 to 0·131 per cent. (0·56 to 9·17 grs. per lb.), in beer often $\frac{1}{4}$ to $\frac{1}{2}$ grain per gallon, and in one sample 3 grains per gallon. This danger vanishes if care is taken to use acid free from arsenic, but a more persistent source of arsenic in beer was found in the malt itself. The usual process of drying the malt in kilns with exposure to fumes of gas-coke or anthracite entails risk of contamination by arsenic, in such proportions as $\frac{1}{60}$th of a grain per lb. The most effective remedy here would seem to be drying out of contact with the fumes; but much can be done by selection of non-arsenical fuel, by careful construction and cleanliness of the kiln, so as to avoid arsenical deposits on ledges falling into the malt, and lastly, by "brushing" the malt, whereby the fibrils (which readily become charged with arsenic) and surface dust are removed. At Halifax, in 1902, the use of arsenical malt caused a local outbreak of poisoning among beer-drinkers.

It was estimated that in the outbreak of 1900 at least 3,000 persons were attacked in Manchester and Salford alone, and 6,000 in all. Many attacks were fatal. For some time the nature of the epidemic was obscured by the unusual character of some of the prominent symptoms, more especially the peripheral neuritis and pigmentary changes. In the main, the attacks and their severity bore relation to the consumption of beer, but some of those attacked had apparently consumed but little, while some heavy drinkers escaped lightly. Similar variations in toleration and susceptibility are met with in the therapeutic use of arsenic. A high degree of insusceptibility is recorded in the case of the Styrian *peasants, who take large doses without appare*

effect, and it may be assumed in the case of some arsenic workers. It is important to note, as an aid to diagnosis, that arsenic can be found not only in the urine, but in the hair.

The Reports of the Royal Commission on Arsenical Poisoning, dealing primarily with the outbreak of 1900, call attention also to some risk of presence of arsenic in glycerine, phosphates, boric acid, colouring matters, and other food ingredients. The Commission recommended a penal limit of $\frac{1}{100}$ grain of arsenic per pound, or per gallon, in any food substance.

In the Marsh-Berzelius test, the suspected material is first treated with hydrochloric acid in a suitable vessel. It is then placed in the Marsh-Berzelius apparatus, which consists of a flask for the generation of hydrogen from which passes a drying tube and a glass tube drawn out in the middle and at the end. In this apparatus hydrogen is obtained from pure zinc and pure sulphuric acid, and the substance under examination is placed in the flask. Hydrogen and arseniuretted hydrogen escape through the drying tube, containing calcium chloride, and thence pass into the fine glass tube, which is heated over a Bunsen burner. The arseniuretted hydrogen is decomposed, and the arsenic is deposited on the wall of the narrow part of the tube, and so forms a "mirror." Finally, this mirror is compared with standard mirrors prepared from known quantities of arsenic (*e.g.* $\frac{1}{50}$, $\frac{1}{66}$, $\frac{1}{88}$, and $\frac{1}{100}$ of a grain per gallon). The Reinsch test is less reliable.

A relation has been suggested between arsenical poisoning and *beri-beri*, a tropical disease characterised by peripheral neuritis. Although the etiology of beri-beri is not at present understood, the facts and data hitherto collected do not lend support to this view.

The question of adulteration of alcoholic beverages is too large for consideration here, but, as an illustration, mention may be made of recent work in connection with brandy. In 1876, owing to an outbreak of *phylloxera*, a parasite affecting and destroying vines, the usual output of genuine brandy from the Cognac district was curtailed, and artificial prepara-

tions were substituted for the genuine article. In *Hillyer* v. *Islington Borough Council* (1904), a sample of "fine old pale brandy" proved, on analysis, to contain at least 60 per cent. of a spirit not derived from the juice of the grape. In the absence of any official or legal standard brandy may be defined as an alcoholic liquor the spirit of which is obtained by distillation from the juice of the grape, and which should contain not less than 80 parts by weight of esters (calculated as ethyl acetate) per 100,000 parts by volume of absolute alcohol. In the above sample there were approximately 40 parts of esters, the volume being made up with plain spirit. The court held that this was not genuine brandy, and convicted.

Summary as to relation of Food and Health. From what has been said it will be seen that there are many ways in which health may become affected by articles of food.

1. Certain essential constituents of diet may be deficient or in excess.

2. Poisonous substances may be derived from the vessels in which the food has been kept. Thus tinned provisions (fruit, fish, or meat) may become poisonous, and cider kept in lead glazed vessels may cause lead-poisoning.

3. Injurious substances may be added or substituted accidentally, or by way of adulteration, or by improper processes of manufacture, or by the drugging of animals before death.

4. Certain kinds of food are liable to be occasionally poisonous even in the fresh state (mussel-poisoning), or when grown under unfavourable conditions (oysters, watercress, etc.).

5. Putrefactive changes may have commenced.

6. Poisonous substances may be developed, either as a result of parasitic growth (fermentation) or from, at present, unknown causes (tyro-toxicon).

7. The flesh or milk of an animal suffering from certain specific or parasitic diseases may impart the disease (*e.g.* tuberculosis, trichinosis, hydatids). Actinomycosis affords an instance of somewhat parallel danger from vegetable, as well as from animal, food.

8. Food, and especially milk, may become infected by virus of human origin (diphtheria, enteric fever, scarlet fever).

It should not be forgotten that disease in the individual, or more rarely idiosyncrasy apart from disease, may render certain kinds of food injurious which to ordinary persons are wholesome. Lastly, there are certain accessories of diet which may be injurious if used injudiciously (alcohol, tea).

In the systematic investigation of suspected cases of poisoning by food, help may be obtained by the use of a tabular form, a separate line being devoted to each item of food consumed in the household, with separate columns for each day and for each inmate, *whether ill or not.*

	M. 36. Ill.			F. 34. Ill.			M. 12. Not ill.			F. 5. Not ill.		
	Mon.	Tu.	Wed.	Mon.	Tu.	Wed.	Mon.	Tu.	Wed.	Mon.	Tu.	Wed.
Beef	×		×	×		×	×		×	×		×
Pork		×			×							
Fish		×						×			×	
Potatoes	×	×	×	×	×	×	×	×	×	×	×	×
Cabbage	×	×		×	×		×	×		×	×	
Bread	×	×	×	×	×	×	×	×	×	×	×	×
Butter (fresh)	×	×	×	×	×	×						
,, (salt)							×	×	×	×	×	×
Cheese	×	×	×				×	×	×			
Milk (cooked)	×	×	×	×	×	×	×	×	×	×	×	×
,, (uncooked)	×	×	×	×	×	×		×	×	×	×	×
etc. etc.												

The list should be as complete and detailed as it can be made by the most careful inquiries. When the table is filled up, it will be seen at once what *articles of diet* (if any) were consumed by all the sick *and by none* of those who escaped attack.

CHAPTER V.

SOIL.

The chemical and physical constitution of the soil and the configuration of its surface have an important bearing upon many hygienic questions, particularly in relation to water-supply, burial-grounds, sewage land treatment, sites for buildings, and the prevalence of certain diseases.

Temperature.—The daily variation of temperature ceases to be perceptible at about three or four feet from the surface. The annual variation is unimportant below six or eight feet, very small below 24 feet, and vanishes at 40 feet (*Galton*) or 50 to 100 feet (*Parkes*). The maximum is later as the distance from the surface increases, and at Edinburgh it was found that in trap-rock at a depth of 24 feet the maximum was in January and the minimum in July. The absorption of heat, assuming that the exposure is equal, is determined mainly by the nature of the soil and the presence or absence of vegetation. The absorption by sand being taken as 100, that of clay is about 70, chalk 60, and humus or mould 50. Radiation varies in like manner, but is generally greater than absorption. Trees and shrubs intercept the sun's rays, and on the other hand check evaporation from the surface of the soil, the net result being to render the ground cool and moist in winter, and cool and dry in summer when the leaves are out. The evaporation from leaves is very great, and tends to moisten and cool the air, and abstract water from the soil. Pettenkofer calculated that an oak tree with 750,000 leaves had in the summer months an evaporation equal to eight times the rainfall, and in

Algeria the *Eucalyptus globulus* has been found to absorb and evaporate twelve times the rainfall.* Herbage lessens absorption of heat by the soil, and also true radiation, but increases evaporation and convection owing to the vast surface of the blades of grass. Grass, therefore, like trees, renders the soil cooler and drier, and more equable in temperature.

Earth temperatures are usually determined by thermometers mounted in paraffin, protected by open wooden covers, suspended by a chain at the required depth in the soil (1 to 4 feet or more), and withdrawn at daily or other intervals for reading. An iron tube driven vertically into the ground affords a passage for the thermometer. Systematic records are usually kept of the daily readings of two earth-thermometers (at 1 foot and 4 feet). At greater depths the internal heat of the earth produces an appreciable effect, causing a rise of about 1° Fahr. for every 55 feet.

Moisture.—At a certain point below the surface in permeable soil, all the interstices are full of water, to the complete exclusion of air. This *subsoil water* or *ground-water* extends downwards to the next impermeable stratum. In marshy ground the surface of the subsoil water may coincide with that of the ground itself, and under ordinary conditions it may be from two or three feet to a hundred feet or more below the ground level. The surface of the ground-water is not necessarily horizontal, or parallel with that of the ground. It flows (usually towards the nearest watercourse or the sea) with a velocity that varies with the permeability of the soil, the steepness of the gradient, and the absence of obstruction by roots of trees.† The level is affected by that portion of the rainfall which percolates through the soil; also by the height of water in adjoining streams or seas, and other conditions modifying the

* As regards the air, forests render both the daily and annual temperatures more equable, and increase the humidity (*Galton*).

† In Munich Pettenkofer estimated the velocity of the ground-water to be 15 feet per day.

facility of outflow—artificial drainage, etc. Sometimes the range of rise and fall does not exceed a few inches, but it is more usually several feet.

Above the level of the ground-water the soil, though aërated, is still kept moist by capillary attraction, by evaporation from below, by rainfall, and by the movements of the ground-water. The soil constantly loses moisture by evaporation from the surface, both directly and through vegetation.

The moisture of a sample of soil is estimated by weighing it before (B) and after (A) drying it on a water-bath. Then $\frac{B - A}{B} \times 100 =$ percentage weight of water in sample. The level of the subsoil water is necessarily that of the water in surface wells, and may be gauged by lowering into the well a cord or rod bearing little cups at short intervals, or more simply by means of an index connected by a cord with a float.

When the ground-water rises, it forces air out of the soil, and at the same time may pollute wells by bringing into them the washings of impure soil. As the ground-water falls again it leaves the soil moist and aërated, conditions favourable for fermentative and putrefactive processes in organically polluted soil.

Damp ground is rendered dry, and the level of its ground-water permanently lowered, by subsoil drainage, surface drainage, and opening the outflow. For subsoil drainage "agricultural" pipes, *i.e.* unglazed porous pipes, are laid loosely end to end at the bottom of deep trenches, and covered in. The interval to be allowed between the parallel drains will depend upon the openness of the soil.

Air ("ground-air") is present in all rocks except the very hardest, above the ground-water level. It fills all the space unoccupied by water or solid particles. The proportion by volume varies greatly with the porosity and other conditions of the soil; loose sand

may contain 50 per cent., and humus several times its own volume of air. Ground-air contains moisture, organic matter of animal or vegetable origin, and sometimes NH_3, H_2S, and CH_4. Carbonic acid is in excess, and increases with the depth; it also varies greatly according to the nature of the soil and the intensity of the local chemical changes that are going on in it. Oxygen is in relatively small proportion, and decreases with the depth. At 13 feet Fodor found 14 per cent. of CO_2 and 7·5 per cent. of oxygen. Many causes combine to keep the ground-air in constant movement, among them being wind, percolation of rain, variations in temperature and barometric pressure, and rise and fall of ground-water.

The percentage volume of air in a sample of rock of specific gravity G may be determined by finding its weight when dry (A), and when saturated with water (B). Then $\frac{B - A}{A} \times G \times 100 =$ percentage of air. For loose soils Pettenkofer used two graduated burettes connected together at the bottom by a clamped tube. One burette was filled with water, and the other with dried and crushed sample soil. Water was then allowed to pass upwards through the soil, displacing all the air until it just reached the surface.

$$\frac{\text{No. of c.c. of water used}}{\text{No. of c.c. of dry soil}} \times 100 = \text{percentage of air.}$$

All rocks are more or less permeable, and therefore capable of containing air or water in their interstices. A cubic yard of granite or marble holds about a pint of water, sandstone 25 gallons, and sand 50 gallons.

Chemical Composition.—The mineral constituents of soil are of the utmost variety, but only the organic matters will be considered here. The soil undergoes constant pollution by dead animal and vegetable matter and excreta, which are as constantly

being removed by putrefaction, nitrification, and the influence of vegetation. Apart from such obvious examples as graveyards, manured fields, sewage-farms, and the like, unintentional pollution of the soil goes on upon an enormous scale, especially around dwellings. Nitrates are commonly found in abundance in the soil of any long inhabited place. Carbonic acid and other simple compounds are formed concurrently; offensive gases are given off during putrefaction, but are deodorised and oxidised by passing through aërated soil Vegetable matters are more persistent. They may undergo putrefaction and slow oxidation, but it is not certain that nitrification takes place.

Sometimes the natural level of the ground is artificially raised, constituting what is known as "made soil." This may be ordinary earth, but in the neighbourhood of towns it is a common practice to fill up hollows, and to elevate low-lying sites by trade refuse, ashes, household refuse, and even excremental refuse. From such soil the impurities fairly rapidly disappear, owing to oxidation and washing by rain. Sanderson, Parkes, and Savage found that in about three years most of the vegetable matters in cinder refuse had disappeared; wood, straw, and cloth were rotten, but still distinguishable. Free exposure to air and rain and free outlet for drainage will accelerate the process of purification.

Bacterial Content.—Soil, particularly within a few inches of the surface, contains many bacteria. These have been divided into groups according to function. The *decomposition* or *denitrification* organisms abound particularly in soils possessing a high degree of organic matter, and their *rôle* is to break down compounds of ammonia and nitrogen, yielding free nitrogen, CO_2, water, ammonia, and sometimes nitrites. These latter bodies are oxidised by the *nitrifying* organisms first discovered by Schlösing

and Muntz in 1877. Nitrification is performed in two stages; first, an oxidation from ammonia bodies to nitrites, carried out by the nitrous organism, and secondly, the oxidation of the nitrites into nitrates by the agency of the nitric organism. For the performance of their function these organisms require pabulum, oxygen, a base with which nitric acid when formed can combine, and a favourable temperature. Both organisms are widely distributed in superficial soils (within 12 inches of the surface), and act together and in conjunction for the common purpose of nitrification. In organic solutions, nitrous organisms thrive and nitric organisms do not, the reverse being true in inorganic solutions containing nitrites, in which nitrous organisms are incapable of the oxidation process. The presence of peaty or humous matter appears to preserve the vitality of nitric organisms during the fermentation of ammonia. A third group of allied organisms are the *nitrogen-fixing* bacteria found in soil and in the roots of leguminosæ; their function appears to be, directly or indirectly, the fixation of free nitrogen (symbiosis). This may be performed under the symbiotic condition by the leaves, by distribution in the soil of the root nodules, or by the nodules themselves. It is thus, in part, that clover, vetches, peas, beans, and other leguminous crops increase the amount of fixed nitrogen in the soil, particularly where it is especially small in quantity. Associated with these groups of bacteria are a number of saprophytic organisms, the function of which is not known. Houston has described certain acid-forming microbes in peat.

It would be difficult to over-estimate the value in the economy of nature of the three groups of *organisms* to which reference has been made: they *remove organic* matter and waste animal products, *they carry* on the oxidation processes which are

applied in the bacterial treatment of sewage, and they fix free nitrogen Some at least of the pathogenic organisms are also known to live and multiply in soil, and at least three find in such a medium a favourable nidus. The bacillus of tetanus (*B. tetani*) is common in the soil and dust of certain districts, either in a bacillary form or in the resting stage of spores The presence of this bacillus in jute factories is possibly due to its attachment to the roots of the *Corchorus* in the soil of Bengal. The organisms of quarter-evil (symptomatic anthrax) and malignant œdema are two other examples of pathogenic bacteria in soil.

Recent research has shown that the typhoid bacillus bears a relation to soil. In 1888 Grancher and Deschamps showed that it was able to survive in soil for more than twenty weeks. In 1894 Dempster published the results of his work on the same subject, in which he obtained the bacillus from sand after 23 days, from garden soil after 42 days, and from peat not later than 24 hours. Four years later came Robertson's researches into the growth of the typhoid bacillus in the soil of an ordinary field, from which he was able to isolate the living bacillus twelve months after. Sidney Martin found the organism still alive after 404 days in dry sterilised garden soil; in wet soils it lived but a short time, as also in uncultivated soils which had not been sterilised, and in which ordinary putrefactive germs abounded. Under such conditions the typhoid bacillus appeared to die out rapidly. Lastly, we have the results of the investigations of Firth and Horrocks (1903), who conclude that the typhoid bacillus is able to assume a vegetative existence in ordinary soils and in sewage-polluted soils for as long as 74 days. They further maintain that the controlling factor is an excess or *deficiency of moisture* in the soil rather than organic

nutritive material. From dry fine sand the bacillus was recovered after 25 days; from moist fine sand after 12 days; from damp (rain-water) ordinary soil after 67 days; from damp (sewage) ordinary soil after 53 days; and from ordinary soil dried to the state of dust, after 24 days. In peat the bacillus lives apparently only a few days. Firth and Horrocks, therefore, arrive at a different conclusion from Martin, namely, that the typhoid bacillus is able to assume a vegetative or saprophytic existence for considerable periods outside the body, that it can survive in ordinary earth for over two months, whether the soil be virgin or polluted with sewage, or frozen hard, and that, therefore, it follows that outbreaks of enteric fever may be due to the dissemination (for example by wind or flies) of infective soil dust. Pfuhl of Berlin (1904) has arrived at results confirmatory of these experiments. From moist garden earth he recovered the typhoid bacillus 88 days after inoculation, from dry sand after 28 days, and from moist peat 21 days.

Sewage added to ordinary garden soil leads to a temporary increase only of sewage microbes at the expense of soil microbes, the ordinary soil bacteria eventually ousting the sewage microbes in the struggle for existence. Sandy soil so treated does not recover for some months. The chief kinds of bacteria resulting from such soil treatment are indol-producing bacteria, gas-producing bacteria, spores of *B. enteritidis sporogenes*, *B. coli* and its allies, and streptococci (*Houston*). Further, it should not be forgotten that soil has some power of destroying pathogenic germs as well as sewage organisms.

Among the more important specific diseases, anthrax, tetanus, malaria, enteric fever, cholera, diarrhœa, and yellow fever are closely concerned with telluric conditions. Dampness of soil is favourable

to phthisis and diphtheria, and, according to some authorities, to rickets also. Goitre is often credited with a more indirect relation to the soil (page 76).

Enteric fever and cholera exhibit in certain localities a very definite inverse relation to the fluctuations of the level of the ground-water. In Munich, Leipsic, and elsewhere, it has been found that a fall in the subsoil water, and especially a rapid fall after an unusually high level, is followed by an outbreak of enteric fever. These observations, extending over several years, led Pettenkofer to the conclusion that the conditions requisite for an enteric outbreak are (1) a rapid fall (after a rise) in the ground-water, (2) pollution of the soil with animal impurities, (3) a certain earth temperature, and (4) the presence of a specific organism in the soil. These conditions imply a warm, moist, and well-aerated soil, containing pabulum suitable for the specific microbe. On the other hand, the association of falling ground water with enteric outbreaks is not observed in other localities. It has not been traced in England, as a rule, and, indeed, outbreaks have occurred with rising ground-water. Although the existence of some direct or indirect relation between the two phenomena in Munich cannot be doubted, Pettenkofer's hypothesis is not the only possible explanation. Buchanan suggested that the connection between them may be found in pollution of wells, but Pettenkofer obtained no analytical evidence of this.

The same conditions, according to Pettenkofer, are necessary for the appearance of cholera in an epidemic form.

Malaria, including under that term the various forms of intermittent and remittent fevers, is also, in part, a "telluric" disease. The specific protozoa have at one stage of their development their normal *habitat in the soil* or in surface water, and require

air, a certain degree of warmth, and decomposing vegetable organic matter. A rise of ground-water due to heavy rainfall, or impeded or insufficient outflow, is a common antecedent of severe outbreaks in malarious districts, and many such districts in England and elsewhere appear to have been permanently freed from malaria by improved drainage. Land that has gone out of cultivation may become malarious if the other conditions are favourable. Marshy land, especially if covered with rank vegetation, is the most common *locus*, and estuarial marshes are favourable breeding grounds. Either permanent flooding or drainage will, as a rule, render them non-malarious.

Enteric fever, cholera, and yellow fever are often endemic, a fact that in itself is strongly suggestive of telluric relations. They are also found to flourish best where the soil is polluted with excremental or other animal matter. The same may be said of diarrhœa, and Ballard has shown that outbreaks of summer diarrhœa have a close relation with the earth temperature at a depth of four feet. Soil may become infected by the spores of anthrax or tetanus, and retain the infection for an almost indefinite time.

Buchanan found not only that phthisis mortality bears a direct relation to dampness of subsoil, *i.e.* to height of ground-water, but also that when the ground-water is lowered and the soil dried by artificial drainage, the recorded phthisis mortality falls, in some instances as much as 30 or even 50 per cent. He concluded that there is less phthisis among populations living upon pervious soils, which were higher lying and sloping, than on impervious, low lying, and flat soils. The term phthisis is, of course, to be taken in a broad sense. It appears, also, that dampness of soil is favourable to all affections of the respiratory system, including bronchitis and pneumonia. In the

absence of definite evidence the popular theory that damp and cold soils are conducive to rheumatism and all manner of catarrhs may be provisionally accepted. A high level of ground-water (say within five feet of the surface) is, therefore, objectionable, and it is preferable that it should be fifteen feet or more from the surface; but frequent and extensive fluctuations of level are probably worst of all. The presence of clay, like high ground-water, renders a soil "cold."

Building Sites.—Porous soils, like sand or gravel, with low ground-water, are the warmest, and in the main the most healthy; but they are also the most liable to organic pollution, and the ground-air moves freely in their interstices. Clay, and especially a clay slope, affords a far more healthy site than gravel or sand containing organic matter, the impure ground-air from which is constantly forced out of the soil, and is also liable to be drawn into the interior of houses through the basement. The most unhealthy site of all would be a hollow with impure gravelly soil and high and fluctuating level of ground-water; the most healthy, the summit of a slope with dry, pure, sandy or gravelly soil, and low and stationary level of subsoil water. The foot of a slope often receives the drainage from the higher ground, and there is the same liability to damp at the junction of an upper porous and a lower impervious bed, especially if the strata dip towards the point in question. In tropical regions it is necessary to take into account the tendency of winds to pass up valleys and ravines, from lower to higher levels, during the day, and in the reverse direction at night. The proximity of marshy or "malarious" ground may be dangerous, even if the site itself is otherwise free from objection. Herbage is beneficial, for the reasons already stated, and so too are trees, unless they are

allowed to interfere with light and circulation of air. Manured lands have not been proved to be hurtful; but irrigated lands, and especially rice-fields, which give off organic matter and much moisture, are injurious; and in Italy rice-grounds are not allowed within 14 kilometres of cities, or 1 kilometre of small towns (*Parkes*). There seems to be no good evidence against well-managed English sewage farms. "Made soil" is usually impure and unfit for building sites. The objection is greatest when the deposit is recent (within 3 years) and contains excremental or other organic refuse, and is so placed in hollows that drainage and aëration are impeded.

Geological Formations.—The following is a summary of Parkes's conclusions in respect to the healthiness of certain geological formations, but, as he points out, they are of less importance than the immediately local conditions:—

Granitic, Metamorphic, and Trap rocks, Millstone Grit and Clay Slate are impervious and generally healthy. The slope is great, vegetation not excessive, air dry, and water pure. Marshes are infrequent. These rocks, when weathered and disintegrated, are alleged to be unhealthy.

Limestone, Oolite, and Magnesian Limestone (*Dolomite*) have also much slope, and water passes off readily. Marshes may occur, even at great heights. Magnesian limestone is the worst and oolite the best. Goitre and calculus may be met with.

Chalk is healthy if permeable and free from clay. The air and water are pure. Goitre and calculus are less common than in limestone districts. Marly chalks are impermeable, and therefore damp and cold, and may be "malarious."

Sandstone, if permeable, is healthy. The air and soil are dry, but the water is often impure. An admixture, or substratum, of clay may render the site damp.

Sand is healthy if pure and dry. Many sandy soils are unhealthy, *e.g.* when the subsoil water is high and organic impurities are present. The water is liable to contain salts of the alkalies, lime, magnesia, and iron, and is often unfit for drinking purposes.

Gravel is healthy, except in hollows where the ground-water is high. Gravel hillocks are the healthiest of all sites. The water is usually pure.

Alluvial soils, including Clay and dense Marl, are usually unhealthy. Water neither runs off nor through them, marshes are common, the air is moist, and the water often impure with lime and soda salts. The deltas of great rivers present these alluvial characters in the highest degree, and should not be adopted for sites without thorough drainage.

Much may be done to improve a site not naturally healthy. If damp it may be drained, or trenches may be cut around it so as to intercept the subsoil water on its way from higher ground. By such means the level of the ground-water will be lowered and its fluctuations lessened. Damp places near the site may be drained or filled in, and the site itself may be artificially elevated if necessary. Trees are often desirable for shelter or ornament, but should not be allowed to interfere with light or circulation of air. Rank or superabundant vegetation must be cleared away, but short grass is beneficial.

CHAPTER VI.

BUILDINGS.

Materials and General Construction.— Most of the ordinary building materials are pervious to air and water to a greater or less extent. Galton states that with a temperature of 40° F. outside, and 72° F. within, the volumes of air passing through a square yard of wall vary according to the material, as follows :—

Sandstone . . .	4·7 cubic feet per hour.
Quarried Limestone .	6·5 ,, ,,
Brick	7·9 ,, ,,
Limestone . . .	10·1 ,, ,,
Mud	14·4 ,, ,,

The thickness of the wall is supposed to be the same in all cases. Mortar, cement, and concrete* are also permeable, and the caustic lime they contain absorbs carbonic acid until it becomes saturated. Wood in its natural condition absorbs water, and the inevitable joints and crevices admit of the passage of air and water. Bricks are usually 9 in. × $4\frac{1}{2}$ in. × $2\frac{3}{4}$ in. They are porous and absorbent, but if of good quality make excellent building material. Stone varies greatly in consistence and durability. Portland stone is much used in the metropolis.

By painting, varnishing, and other means the inner surfaces of walls, floors, and ceilings can be rendered impervious, and walls lined with glazed bricks or the finer cements (Parian) are scarcely permeable.

* *Mortar* consists of sharp sand and slaked lime in the proportion of 3 to 1. Frequently inferior material is worked up into mortar. *Portland Cement* is made by grinding chalk and mixing it with blue clay and river mud, then burning it in a kiln and grinding it to a fine powder. "Compo" is a mixture of Portland cement with sand for external plastering in two coats, a rough coat composed of 1 part cement to 5 parts compo, and a fine coat of 2 parts fine sand and 1 part cement. With this material walls are "rendered." *Concrete* is composed of 3 parts broken ballast, 2 parts sand, and 1 part lime or cement.

The disadvantages of porous materials are obvious, and the air admitted in this way though small in amount is at least doubtful in purity. Pervious walls are liable to be damp and cold. Air passing through them in either direction is filtered, and the wall becomes charged with organic impurities. This is specially the case with the inner surfaces, and in hospitals it is now customary to render the walls and floors impervious as far as possible. The exclusion of damp and impure ground-air, by means of impervious basements, is absolutely necessary in all inhabited buildings. This may most conveniently be effected by covering the basement in every part with a layer of concrete six inches thick, as required by the Model Bye-laws, but other materials may be employed. It has been proposed to cut off the communication with the soil still more thoroughly by elevating the house upon pillars and arches, thus allowing free play of fresh air beneath it. If there are no cellars, the same result may be attained in some degree by constructing the lowest floor a foot or two above the ground level, and freely ventilating the space beneath by means of large air-grates. In houses built

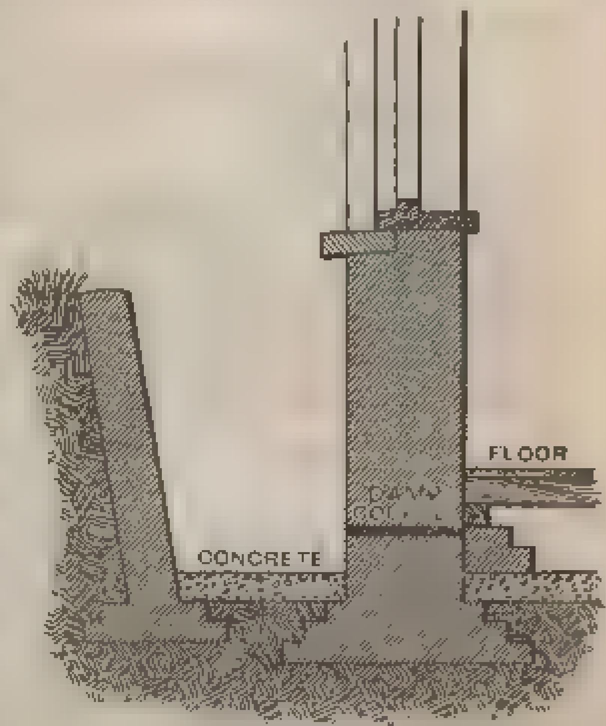

Fig. 5.—Damp-course.

without precautions of this kind the entrance of ground-air through the basement is inevitable whenever the air in the interior of the house is warm, and therefore lighter than that outside.

Measures must also be taken to prevent damp from rising in the walls by capillary attraction. For this purpose a "damp-course" must be provided, that is, a continuous horizontal course of glazed earthenware, sheet lead, two layers of ordinary roofing slate set in cement, $\frac{3}{4}$in. of asphalt, stoneware slabs, two courses of Staffordshire bricks, or other impervious material, of the full thickness of the wall, above the highest point at which the wall is in contact with the earth, and below the lowest timbers or floor supports (Fig. 5). It is undesirable to allow the soil to be in contact with the wall of any room or cellar, and this can usually be obviated by excavating it on the outside to below the level of the floor so as to form a "dry area," but if this is impracticable the device shown in the Model Bye-laws may be employed; the wall is made hollow up to a point above the ground level, and two damp-courses are inserted, one at the level of the bottom of the cavity, and of

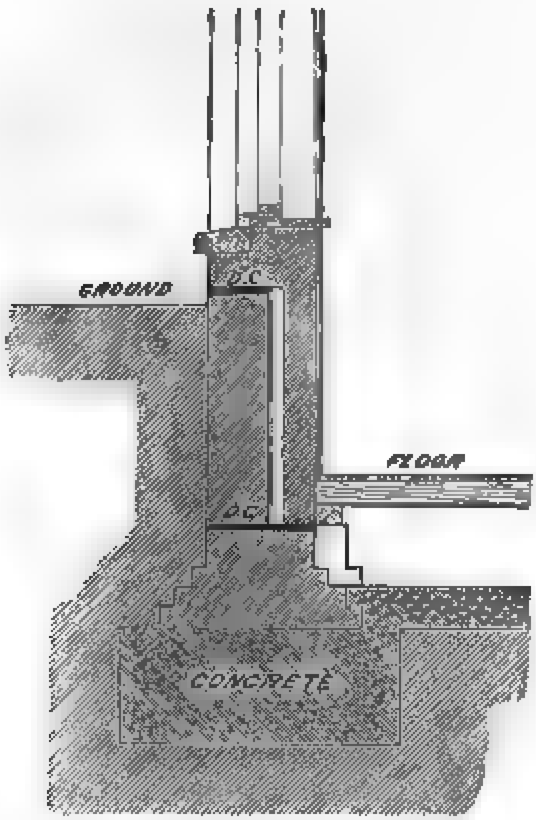

Fig. 6.—Double damp-course Soil abutting upon hollow wall.

course beneath the floor level, the other at the top of the cavity, and, therefore, above the level of the ground outside (Fig. 6). In this way the inner wall is completely isolated from the soil.

The necessity for free ventilation extends to all closed spaces, including those below floors. There is a tendency among builders to use air-grates so constructed and arranged as to allow but little air to pass. If the ventilation is insufficient, the air becomes damp and musty, and the fungous growth known as "dry-rot" (*Merulius lacrimans*) is liable to set in. As regards the upper storeys, however, the ventilation through the boards and ceiling is usually sufficient to prevent dry-rot, unless the floor is covered with oilcloth or otherwise rendered impervious. Fireproof floors are now becoming common.

The thickness of walls is often regulated solely by considerations of stability, and the choice of materials by their cheapness and convenience, but regard should also be had to warmth and exclusion of damp. It is sometimes advantageous to make the outside wall hollow or double, or even to fill in the hollow of a double wall with pitch or cement. The outer surface may also be made impervious by paint, tar, cement, or slate. Damp walls may be due to ascending moisture where there is no damp-proof course, or to overflow from roof-gutters and rain-water pipes, etc. The walls separating one house from another should be carried up to or above the roof in every part. Any communication beneath the roof is objectionable for many reasons, including danger in case of fire or infectious disease in one of the houses. The Model Bye-laws require for the external walls or party-walls of houses a minimum thickness of nine inches, increasing according to a prescribed scale when the height exceeds 25 feet or the length 30 feet. Walls should be properly bonded by Flemish

bond (bricks placed transversely and longitudinally by turn) or English bond (a course of longitudinal alternating with a course of transverse).

The roof itself affords very little protection from the extremes of temperature, and the rooms immediately beneath it, if intended for occupation, should have a "false roof" or ceiling over them, so as to leave an intervening air-space below the slates.

The size of the rooms will, of course, be regulated by convenience and by the purpose for which they are intended. As a rule, the height should not be less than ten feet, but extreme height is not desirable unless means are provided for carrying away the hot and impure air from the upper part before it condenses and falls again. A window opening top and bottom and placed in an external wall is essential in every inhabited room, and as far as possible a due northern, and therefore sunless, aspect is to be avoided. Besides the window, every room should have an open chimney, or at least some permanent and effectual means of ventilation not entirely under the control of the occupant. Rooms beneath the ground level are liable to damp, stagnation of air, and deficiency of sunlight, and should never be used as bedrooms. A central hall or staircase of the full height of the house, with ventilating windows at the top, is useful in promoting free circulation of air throughout the building.

For the sake of securing a share of sunlight in every room, it is preferable that rows of houses should run north and south, and that square buildings should have angles in those directions.

Every house should have both in front and rear an open space at least equal in length to the height of the building, in order to allow sufficient light and ventilation for the rooms on the lowest floor. *The arrangement* of houses in courts or small

closed squares is objectionable, since the air cannot circulate freely. *Cul de sac* courts and courts entered under archways or by high-walled alleys are on this account to be deprecated. Nor should buildings be so placed in relation to each other as to prevent free access of sunlight and air. The space in front of houses should be of a minimum width of 36 feet for a street of more than 100 feet in length which itself must be at least 24 feet wide (in London 40 feet). Model Bye-laws provide for at least 150 superficial feet at the rear of houses. The London Building Act crystallizes the principle that the amount of space at the rear shall be proportionate to the height of the building, and it contains a number of regulations as to building in new and old streets. Streets should not be of less width than the height of the houses in them, and a line drawn from the ridge of the roof to the foot of the wall opposite, front and rear, should not make an angle of more than 45° with the ground. The practice of building over backyards which prevailed in Central London last century is wholly pernicious, for such a system leads to back-to-back houses.

Back-to-back houses are dwellings in which through ventilation cannot be obtained, and the absence of curtilage at the back is in itself a serious inconvenience. They have usually dark and ill-ventilated sculleries, pantries, storerooms, or living rooms, and it is often difficult to secure the satisfactory disconnection of sink wastes. The closets have to be built in blocks, often at an inconvenient distance, and in a public position. Tatham has shown that in such houses mortality rates are higher, by comparing the death rates in Salford (26·1 per 1,000) where there were no back-to-back houses with the death rates where 18 per cent. of the houses *were of this character* (29·1 per 1,000), and where

50 per cent. were of this character (37·3 per 1,000). Many similar returns have been made, and the **L.G.B.** do not now sanction bye-laws which permit of the erection of back-to-back houses.

The interior of a house will of course be arranged according to the taste and circumstances of the owner. Walls may suitably be rendered in plaster (lime mortar, or cement mortar) and finished by lime-washing, as in outbuildings, whitewashing with "whiting" (chalk, size, and alum), distempering, painting in oils, or papering. Painting of wood, iron-work, etc., has many advantages, and tends to cleanliness and preservation. It may frequently be washed. New papers should not be pasted over old ones, as this leads to filth, and, in tenement houses, to verminous conditions. The wall should be "stripped" and cleansed, and, if necessary, rendered with size before the new paper is put on.

New houses are constructed under the supervision of the **S.A.**, and in accordance with bye-laws prescribing all details necessary for sanitary purposes. Old houses are very often wanting in many points now regarded as essential for the health of the inmates, and it becomes a matter of considerable difficulty to decide how far it is practicable to enforce modern requirements in such houses. If the defects are such as to be prejudicial to the health of the inhabitants, it is the duty of the **S.A.** to require the necessary repairs or alterations to be carried out, and it is incumbent upon the **M.O.H.** and Inspector of Nuisances to bring such cases to the notice of the Authority for that purpose. Very often it is not possible to effect such alterations as would be considered satisfactory in new premises, and a certain degree of latitude has to be allowed. No hard and fast line can be drawn between that which is essential and that which is desirable, and a similar difficulty

frequently arises in deciding whether a house is or is not fit for habitation. Sometimes the question is only one of degree, in matters regarding which fixed standards are impossible. Several causes may combine to render a house unhealthy.

Water-Supply to Houses.—The Public Health Act, 1875, and the Public Health (Water) Act, 1878, give powers to **S.A.** to enforce supply of water to individual houses, groups of houses and villages.

Under the 1875 Act, the **S.A.** can only insist on a supply to a house if the cost does not exceed the water rate authorised by any local Act in force in the district, or 2d. per week, or such other cost as the **L.G.B.** may, on the application of the **S.A.**, determine to be reasonable.

The Public Health (Water) Act, 1878, makes it the duty of a Rural **S.A.** to see that every occupied dwelling-house in their district "has within reasonable distance an available supply of wholesome water," but, unfortunately, the interpretation of "reasonable distance," and "an available supply," has in the past often been so liberal that the Act has been largely inoperative.

The Metropolis Water Act, 1871, gave power to the Board of Trade to make regulations controlling the supply to houses by water companies. The Public Health (London) Act, 1891 (s. 48), states that a dwelling-house shall be deemed unfit for human habitation if it is without a proper and sufficient supply of water. New houses in London have to be certified in this respect.

Ventilation.—One of the most important matters in connection with buildings, particularly dwelling-houses, is ventilation. Taking the average frequency of respiration as 16 per minute, and the average volume of each breath as 30 cubic inches, the volume of air expired is about 17 cubic feet per hour,

and if it were possible to carry this immediately away (as is done in the case of divers) a fresh-air supply of 17 cubic feet per hour would suffice. In practice, the expired air cannot be prevented from mixing with the rest, and we have to determine how much fresh air is needed to dilute down the respiratory impurities to a permissible point, assuming that the whole of the air in the room is equally contaminated.

When the carbonic acid in the air of a room exceeds 0·6 volume per 1,000, the air begins to be perceptibly "close" *to a person entering from the open air*, and it is usual to adopt this as a standard of purity, and to aim at introducing a sufficient supply of fresh air to keep the carbonic acid at or below this point.

A thousand cubic feet of fresh air, containing 0·4 cubic foot of carbonic acid (see page 3), can therefore take up 0·2 cubic foot more without exceeding the limit of 0·6. As already stated, an average man gives off 0·6 cubic foot of carbonic acid per hour, so that $\frac{0\cdot6}{0\cdot2} \times 1{,}000$, or 3,000 cubic feet of fresh air per hour, are needed to maintain the standard of purity. If other values be adopted for any of the preliminary data, the volume of fresh air needed will be proportionately modified. In general terms, if

A = no. of c.f. of CO_2 in 1,000 c.f. of fresh air = 0·4,
C = proposed max. limit of CO_2 in the air of the room,
R = no. of c.f. of CO_2 given off per head per hour = 0·6,
F = volume of fresh air required per head per hour to maintain the standard C,

Then $F = \frac{R \times 1{,}000}{C - A}$, and for n persons the required volume becomes $\frac{n \times R \times 1{,}000}{C - A}$, or $\frac{n \times 600}{C - 0\cdot4}$

Example I.—What hourly supply of fresh air is needed for a hall containing 100 persons, in order that the air of the

hall may not contain more than 0·7 part of carbonic acid per 1,000 volumes of air?

Answer: $F = \dfrac{100 \times 600}{0{\cdot}7 - 0{\cdot}4} \times 1{,}000 = 200{,}000$ cubic feet.

Example II.—If 12,000 cubic feet of fresh air per hour are supplied to a room containing 10 persons, what proportion of carbonic acid will be found in the air of the room?

The formula $F = \dfrac{n \times 600}{C - A}$ becomes

$$12{,}000 = \frac{10 \times 600}{C - 0{\cdot}4}$$

Hence C = 0·9 per 1,000 cubic feet.

It is of course assumed that an equal volume of impure air is removed to make way for the fresh air.

Carnelley, Haldane, and Anderson find that the determination of carbonic acid alone is not a satisfactory measure of the impurity of the air in other respects. There is no definite connection between the number of microbes and the amount of CO_2, but in general a high proportion of CO_2 is accompanied by a high proportion of organic matter. Nor does it of course include other impurities, such as sulphur.*

As gas forms in burning about half its volume of CO_2, the products of combustion (on a standard of 20 grains of sulphur per 100 cubic feet) would contain less than 0·5 grains of sulphur to 500 litres of CO_2. If the sulphur were oxidised to SO_2 this would correspond to about one volume of SO_2 to 1,500 volumes of CO_2, which would not produce any perceptible effect in the atmosphere of a room. The sulphur contained in crude unpurified lighting gas is present chiefly as H_2S, about one-tenth being present in other forms (as CS_2). Gas which is purified from carbon bisulphide is greatly superior from a hygienic

* The English gas companies are usually legally required to supply gas containing less than 20 grains per 100 cubic feet. In London hitherto the maximum has been 17 grains in summer and 22 in winter. In some provincial towns as much as 30 is allowed.

standpoint to gas which is only purified from sulphuretted hydrogen.

As regards the more specific diseases, the injurious effects of deficient ventilation are obvious. Crowding in a common atmosphere has long been known to be disastrous in typhus and erysipelas, and more recent experience has established this in respect of diphtheria, influenza and other maladies, both as regards transmission of infection and intensification of type, or retardation of recovery. Ventilation has greatly lessened phthisis in barracks and other institutions, and with cleanliness it has banished typhus from prisons, and hospital gangrene and erysipelas from hospitals. The success of the open-air treatment in camp hospitals and in sanatoria for phthisis has the same significance. It is evident that all diseases in which the breath is infectious must necessarily be more readily transmissible when the expired air is rebreathed in a concentrated form.

Apart from this there is abundant evidence of the gain in comfort, general health and longevity under conditions of adequate fresh air supply, and conversely of higher death rates (general, and from bronchitis and other non-specific causes), impaired health, anæmia, headache, and depression among those whose lives are largely spent in ill-ventilated rooms. Some of these effects are felt at once by susceptible persons on entering a room in which others work without discomfort, but the precise relation between them and the several physical conditions which impurity of air connotes, is not clear. Experiments have been made, with conflicting results, by removing one or other of these conditions while leaving the rest to increase in a degree far beyond that met with in practice. Thus, in experiments by Haldane and Lorrain Smith *carbonic* acid alone did not appear to disturb *respiration until it* had risen from 4 to 300 parts per

10,000; nor did diminution of oxygen do so until the proportion had fallen from 21 to 12 per cent. of the air. But if CO_2 be removed, the accumulation of organic matter, which is usually regarded as the most harmful factor, seems to produce little effect. Humidity alone cannot be held responsible, for it may approach saturation even in the open air. Haldane is inclined to attach some importance to the depressing influence of the smell which accompanies want of ventilation.

There is, however, no doubt as to their combined effect, and it must be remembered that experimental conditions do not attempt to imitate those of daily life, in duration or in attendant circumstances such as exercise. The one is rather a question of acute poisoning, the other of chronic poisoning

Air space.—With ordinary appliances, and under the average atmospheric conditions of the climate of England, the air of a room cannot be changed more than about three times per hour without causing an inconvenient amount of draught. Hence, in order to supply 3,000 cubic feet of fresh air per hour, we should have an air space for each person of at least 1,000 cubic feet. In calculating this, only the available air-space should be taken into account, deduction being made for furniture and other solid objects. It must be remembered, too, that air stagnates in nooks and corners, and the useful part of the air-space is that in which the air moves freely. For these and other reasons it is more difficult to provide for the efficient ventilation of a small room than of a large one, the air-space per head being the same in each case; but on the other hand the transpiration through walls, ceilings, and floors is relatively greater in small rooms, owing to their higher ratio of surface to air contents. The extent and practical importance of this transpiration is proved not only by CO_2 determinations but by the

experience gained in sulphur fumigation where the leakage of the gas is rapid and demonstrable in spite of every precaution to prevent its escape through openings.

A further reservation is necessary. Above a certain height air-space ceases to be useful, since it does not assist ventilation; and in such circumstances increase in height cannot compensate for inadequacy in length and breadth, that is, floor-space. There may be overcrowding and even suffocation in the open air. It is a common rule, in rooms of moderate size, to disregard height above 15 feet in calculating air-space, but the limit varies with the floor area. In the special rules for certain dangerous processes under the Factory Act, the requirement of at least 400 cubic feet of air-space per head is coupled with a condition that height above 14 feet is not to be taken into account. In hospitals and schools there is a standard of floor-space per bed, apart from mere cubic capacity.

AVERAGE RESULTS OF ANALYSES OF AIR IN SLEEPING ROOMS BETWEEN 12.30 AND 4.30 A.M. (*Carnelley, Haldane, and Anderson.*)

Cubic Feet per Head.	Temperature (Fahrenheit.)	Carbonic Acid per 1,000 vols.	Organic Matter (vols. of Oxygen required per million vols. of air).	Microbes per litre.
100–180 . .	55°	1·15	15·1	80
180–260 . .	54°	1·07	15·1	49
260–340 . .	53°	1·03	11·8	32
340–500 . .	57°	0·92	8·4	42
500–1,000 . .	54°	0·86	5·6	6
1,000–2,500 . .	53°	0·67	3·9	9
2,500–4,000 . .	57°	0·79	5·0	13

The experiments summarised above were made in Dundee. They tend to show that about 1,000 cubic

feet per head are sufficient, and, indeed, the impurities were somewhat greater when very large space was provided, owing probably to imperfect ventilation.

The same observers compared houses of one, two, three, and four rooms, in regard to impurity of air and mortality from different causes among the inmates. They found that the smaller the tenement the greater was the impurity of the air, as shown by increase of carbonic acid, microbes, and organic matter. The death-rate increased in like manner, and especially among children. Comparing one-roomed with four-roomed houses, the general death-rate was doubled, and the death-rate at ages below five years quadrupled. The increase was most marked in diarrhœa, measles, whooping cough, bronchitis, and pneumonia. The same general conclusions are well illustrated in the following table :—

Finsbury. Death Rates (per 1,000 living), 1903-4.

Size of Tenements (Number of Rooms).	Census Population, 1901.	All Causes.		Principal Zymotic Diseases.		Phthisis.		Respiratory disease (excluding Phthisis).	
		1903.	1904.	1903.	1904.	1903.	1904.	1903.	1904
One	14,516	38·9	40·6	5·6	5·1	4·5	4·5	9·3	9·8
Two	31,482	22·6	21·9	3·8	4·1	2·8	2·2	5·3	4·9
Three	21,280	11·7	14·7	1·8	2·1	1·2	2·3	2·4	3·4
Four or more	33,185	5·6	7·5	0·54	0·1	0·63	1·2	0·84	1·4
The Borough	101,463	19·6	21·1	2·6	2·8	2·2	2·5	3·9	4·8

The actual air-space obtained in practice frequently falls very far short of 1,000 cubic feet per head, even in large private houses. In registered common lodging-houses the minimum is usually 300 cubic feet per head, but varies according to the regulations of the different local authorities, and in working-class

dwellings it is frequently much less still. The London Education Committee require 120 cubic feet per head as a minimum in primary schools (96 cubic feet in infant schools). The lowest standard expressly sanctioned by law is that for canal-boats, namely, 60 cubic feet per head for adults, and 40 for children. It is important to bear in mind that air-space is chiefly valuable as making ventilation possible without "draught," and not as a store of fresh air. The foul air of an average English bedroom in the morning is a proof that proper ventilation has not been provided, whatever the magnitude of the cubic space. No bedroom, however large, ever contains a sufficient supply of fresh air for the night, but the larger the room the more readily can efficient ventilation be contrived. A thousand cubic feet of space per person is ample, if the air is changed three times per hour, but in itself a thousand cubic feet of air is a sufficient supply for one person for twenty minutes only, if the CO_2 is to be kept down to 0·6 per 1,000.

The objection to draught is largely dependent upon its chilling effect, so that in hot weather, or when the fresh air is warmed artificially, the air of a room may be changed more rapidly than three times an hour, and in that case a somewhat smaller cubic space may be sufficient.

Although the carbonic acid of expired air diffuses readily, the organic matter is less volatile, and hangs about in invisible clouds unless dissipated by local currents. Hence the composition of air in an occupied room is not uniform, even at the same level, though for practical purposes it may usually be assumed to be so. In a large room occupied by many persons both the local currents and the foci of pollution are numerous, so that the composition of the air is much more uniform than in a small room

occupied by one person. If from any cause the air passing out of the room is not the most impure, the remaining air will be found to exceed the theoretical degree of impurity. The outlet should be at or near the highest point, since expired air, being warm and moist,* is lighter than ordinary air, and ascends at first to the upper part of the room.

The fresh air inlets should be arranged as far as possible so as to avoid draughts impinging upon the occupants, to secure diffusion of the current, and to counteract the tendency of the fresh air (if cool) to sink to the lowest level. This may be effected by giving it an upward direction on entering, so that before descending it mixes with the air of the room.

In measuring a room for the purpose of calculating the air space, recesses and projections may be taken separately, and then added to or deducted from the total. A similar procedure will obviate any difficulty in cases where the ceiling is not horizontal throughout.†

The ventilation of a room or building may be "natural" or "artificial," the latter term being applied to mechanical means for extraction or propulsion of air, and the former to all other forms of ventilation.

Natural ventilation is dependent upon wind,

* The vapour of water is lighter than air. The volumes occupied by 18 parts by weight of water vapour, 32 of oxygen, and 28 of nitrogen, are equal, these proportions being, of course, those of their respective molecular weights.

† Very often only right angles are met with, so that the floor area = length × breadth, and the cubic capacity = area × height. The following rules cover most of the other conditions likely to occur in practice:

Area of triangle = Base × Height × ½. (Euclid I. 41.)

Area of an irregular four-sided figure. Divide into two triangles, by joining two opposite angles. Find area of each triangle, and add together.

Area of a circle = (Diameter)² × 0·7854.

Area of a semicircle = (Diameter)² × 0·3927.

Area of segment of circle = Chord × Height × ⅔ + $\frac{(\text{Height})^3}{2 \times \text{Chord}}$

Area of an ellipse = Long Diameter × Short Diameter × 0·7854.

Capacity of a dome = Area of base × Height × ⅔.

Capacity of a cone or pyramid = Area of Base × Height × ⅓.

upon local currents due to differences between internal and external temperatures, and still more upon local currents determined by artificial heat, as in chimneys or ventilating gas-lights, although these last may perhaps more properly be considered as artificial means of ventilation.

Air finds its way into a room by the doors and windows, however close-fitting, and to a less extent through brick or stone walls, ceilings and floors. These leakages are very small if a proper fresh-air inlet has been provided. Such inlets may be window openings, or ventilating fire-places or stoves, or special openings (ventilators). Windows should be made to open at top and bottom, but it is desirable to have in addition some means of admitting air at all seasons without draught. This may be done by having double windows, or one or more double panes, and providing an opening at the bottom of the outer and at the top of the inner one, so as to admit fresh air in an upward current. Louvred panes and several modifications of "hit-and-miss" ventilators are also available. A simple and effectual device (Hinckes-Bird's) is to place a board beneath the lower sash, propping it up and filling in the space below while providing a way for an upward indraught between the two sashes. Another plan is for the upper part of the window to be hinged below, so as to fall forward and admit air into the room as by a Sheringham valve.

Ventilating fire-places have an air-chamber at the back of the grate, heated by the fire. Fresh air brought by a pipe from outside is warmed in the hot chamber, and then passes into the room. There are many varieties, among which Galton's is the earliest and one of the best. Ventilating stoves are in use, the fresh air entering through a coiled pipe exposed to the heat of the stove.

Special ventilators (Fig. 7) are of varied types, from simple openings through the wall to the most complex arrangements. *Perforated bricks* cause little draught, the holes being conical with the wider ends inside, so that the air stream slackens as it passes through the wall, and is diffused upon entering the room. *Sheringham's ventilator* is a small vertical flap door in the wall near the ceiling, balanced by a counterpoise and hinged below so as to fall forward towards the room; it is cased in at the sides and front so that the current can only pass upwards. *Tobin's ventilator* consists of a large upright tube rising five feet or more from the floor; fresh air from outside passes up this tube and into the room. *Ventilating* cornices are made,

consisting of a double channel of perforated metal, cold fresh air being brought into the room by the lower channel, and vitiated air being received into the upper channel and carried to the chimney or other outlet; another plan is to carry a perforated inlet tube along the cornice on three sides of the room, and a similarly perforated outlet tube along the fourth side. A hollow perforated metal beam, interrupted by a diaphragm

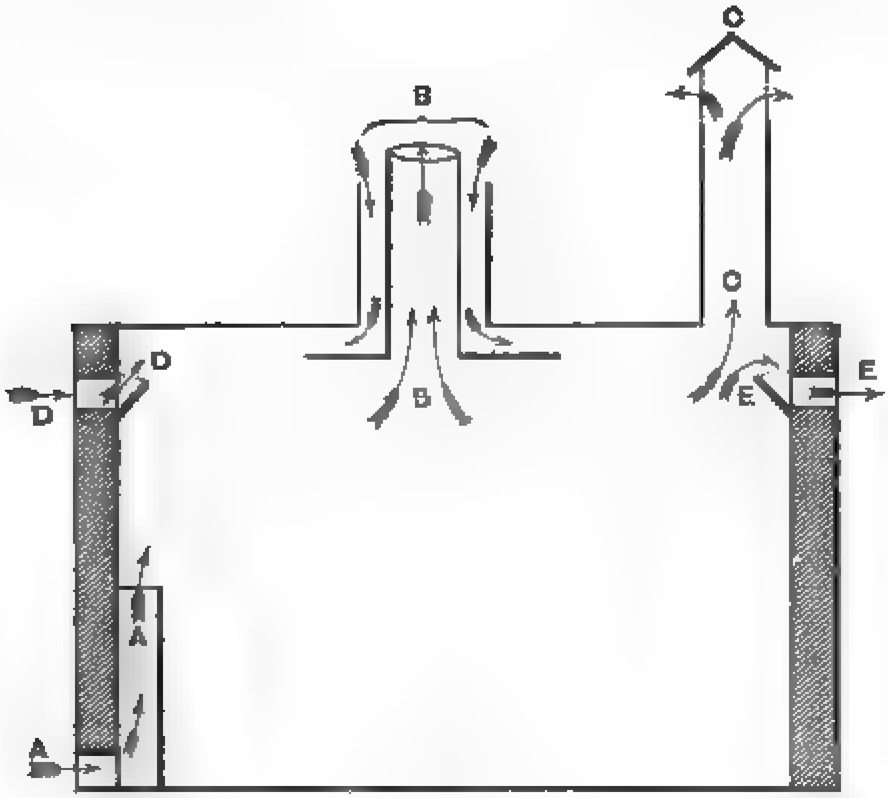

Fig. 7.—Ventilators.
A A, Tobin's; B B, McKinnell's; C C, simple ventilating shaft, with cap; D D, Sheringham's (acting as inlet); E E, Sheringham's (acting as outlet).

at the centre, may be taken across the room, one-half serving as an inlet and the other as an outlet, according to the direction of the wind. *McKinnell's ventilator* consists of a larger outer and a smaller inner tube, carried upwards through the ceiling; fresh air passes in between the tubes, and is dispersed on entering the room by a horizontal flange upon the inner tube; the inner tube, which is equal in sectional area to the inlet, and projects beyond the other both above and below, carries off impure air. Another device is a vertical shaft divided longitudinally into two or four separate channels, along which

currents in opposite directions will always establish themselves. Workrooms may be ventilated by means of a perforated ceiling of zinc or paper, over which is a chamber open to the outer air on every side. An open-tiled roof, or one not underdrawn, allows much ventilation.

Some of the preceding are intended to act as inlets, but all are liable to become outlets. Other kinds of ventilators are, like chimneys, designed as outlets only. An opening may be made from the room into the chimney near the ceiling, reflux of smoke being prevented by a number of little valves of mica (Boyle's valves) which, in the absence of up-current, close by their own weight, owing to the forward tilt of the latticed framework to which they are attached. Ventilating gas-lights are made, in which the products of combustion are collected by means of a bell cover or glass globe, and conveyed away by a tube; this tube can be surrounded by a larger one, and the heated space between the two made to act as a further extraction shaft. A similar use may be made of chimneys, the smoke being contained in a central metal tube, leaving a heated air-space all around it, which serves for extraction. Or outlet pipes from the higher part of the room may be carried upwards for some distance in or close to the chimney so as to utilise its heat in promoting an up-current. Extraction tubes may of course be carried from any part of the room, with or without taking advantage of these various convenient sources of heat, and they may be provided with cowls.

The size of openings required for the efficient ventilation of an occupied room under average conditions is about 48 square inches *per head*, namely, 24 as inlet and 24 as outlet, but, according to Parkes, no single inlet should exceed 60 and no outlet 144 square inches.

Supplies of fresh air should be taken from suitable points free from risk of contamination, and, if necessary, the air may be screened through metal gratings, canvas, cotton wool, &c. It may be washed by passing it through spray or a film of water, or by being made to impinge upon a tray containing water, and it may be warmed by means of ventilating fire-places or stoves, or by coils of hot-water or steam tubes at the inlet. If warmed, there is advantage in introducing fresh air at or near the floor level; but if cold, it is necessary to avoid draughts which might impinge upon any

person in the room, and therefore the air is delivered at a higher level and with an upward direction.

Outlets should be as near the chimney as possible; the air in that part is the warmest, as well as the most impure, so that the worst air is removed with the maximum velocity.

Any barometric pressure P may be regarded as produced by the weight of a column of air *of uniform density* and of height H. "Montgolfier's Rule" affirms that air under pressure will rush into a vacuum with a velocity equal to that acquired by a body falling from the corresponding height H, which velocity may be determined by the formula $V_2 = 2gH$, g being the acceleration due to gravity (32·18 feet per second), and V the velocity required. Thus under standard conditions of barometer and thermometer H is about 5 miles, or 26,400 feet, so that $V_2 = 2 \times 32{\cdot}18 \times 26{,}400$, and V = about 1,300 feet per second.

If, however, the air under pressure P passes not into a vacuum but into space containing air under a low pressure p, the formula requires modification, the velocity being dependent upon the difference between P and p. It becomes necessary to calculate the height h of a uniform column of air (of the same standard of density as was adopted in determining H), which would give the pressure p.

The formula then becomes $V_2 = 2g\ (H\text{-}h)$, and in this form it is applicable to problems of ventilation.

For example, it may be required to determine the theoretical velocity of updraught in a vertical* flue x feet long, leading from a room containing air at a temperature $t°$ into the open air of lower temperature T°. An inlet for cold air is presupposed. The column of heated air in the flue may be regarded as balanced against an equally high column of cold air outside in a sort of U-tube, and as yielding to the greater weight of the colder and less rarefied column, and the (equal) weights of these two columns correspond to P and p. The barometric pressure at the level of the top of the flue may be neglected, since it affects both columns alike. Then taking the density of the outside air as the standard, the height x may be put for H in the formula, and it only remains to determine h, the height of the heated column when reduced to the same standard density. Air expands with heat to the extent of ·002

* The *vertical* height only must be taken, even if the course of the flue is oblique or bent.

of its volume for each degree Fahr.,* and hence 1 volume at T° becomes, at $t°$, $1 + \cdot 002\ (t\text{-}T)$, so that the column of hot air of height x at $t°$ corresponds to a height $x \times \frac{1}{1 + \cdot 002\ (t - T)}$ at the standard temperature T. This, then, is the value of h, and

$$V_2 = 2g\left(x - x \times \frac{1}{1 + \cdot 002\ (t - T)}\right).$$

Since $\sqrt{2g}$ is approximately 8·0, the formula may conveniently be written.

$$V = 8\sqrt{x - \frac{x}{1 + \cdot 002\ (t - T)}}.$$

If, as an example, the external and internal temperatures are respectively 40° F. and 60° F., and the height of the flue 20 feet,

$$V = 8\sqrt{20 - \frac{20}{1 + \cdot 002\ (60 - 40)}}.$$

Hence the theoretical velocity of draught is 7·1 feet per second, and this multiplied by the sectional area of the flue gives the number of cubic feet discharged per second.

The theoretical velocity is subject to correction for friction, which varies directly as the length of the tube L and the square of the velocity, and inversely as the diameter D, that is as $\frac{V_2 L}{D}$. In practice an allowance of $\frac{1}{4}$, or even $\frac{1}{2}$, has to be made for friction, which is also increased by angles in the course of the flue.

The following formula by De Chaumont is convenient for ascertaining the relation between the size of the opening and the hourly delivery of air:—

$$D = 200 \times \Phi \times \sqrt{\cdot 002 \times x \times (t - T)},$$

where D = delivery of air, in cubic feet per hour,

Φ = the sectional area of the tube, or of the inlet or outlet, in square inches,

x = height of heated column of air, in feet,

t and T = the internal and external temperatures respectively.

Thus, if the heated column be 20 feet in height, the internal and external temperatures 60° F. and 40° F., and the required

* Strictly speaking, this is accurate only when T = 32° F., but the error is immaterial for the present purpose.

delivery 6,000 feet per hour, the formula will give the sectional area necessary :—

$$6000 = 200\,\phi\,\sqrt{\cdot 002 \times 20 \times (60 - 40)},$$
$$\phi = 33{\cdot}56 \text{ square inches.}$$

The linear velocity with which air passes through an opening may also be determined experimentally by an *anemometer*, which should be placed, not at the centre, but about $\frac{2}{5}$ of the diameter from the side of the opening, so as to obtain the mean velocity. Very delicate anemometers are made, consisting of four light metal vanes mounted obliquely upon a common axis, the revolutions of which are indicated automatically upon dials. The registering apparatus can be thrown in or out of gear by a spring catch, while the vanes are revolving, so that the time can be determined accurately. The linear movement observed during one minute, or less, is readily converted into velocity per hour or second, and this, multiplied by the sectional area of the opening, gives the cubic discharge.

Artificial ventilation involves either propulsion or extraction of air, the establishment of a *plenum* or *vacuum* in the room to be ventilated. Fresh air may be driven into a room or building by revolving fans or other motors ; vitiated air may be extracted by means of fans, steam jets, or a heated outlet shaft. The fans used for the purpose have vanes set obliquely upon a rapidly revolving axis, and work in a closed box or tube so as to propel a constant current of air of any required volume and velocity, somewhat after the manner of an Archimedean screw. Steam allowed to escape in a powerful jet into a flue is capable of carrying with it 200 times its own volume of air. Gas burnt at the foot of an extraction shaft may be made to carry off a thousand times its own volume of air.

Heat is by far the most generally employed motive power. Ordinary fire-places, chimneys, and ventilating gas-lights act in this way. Special extraction shafts, with gas jets or furnaces at the bottom, are common. Mines are ventilated by means of a furnace at the foot of the upcast shaft, air being drawn down another shaft and made to traverse the whole of the

workings on its way to the upcast. A similar plan is adopted in steamers, the upcast being a space around the funnel and boilers, a contrivance which has been applied also to house chimneys by confining the smoke, etc., to an iron tube passing up in the centre of the chimney shaft. Extraction is necessary where dust and fumes have to be drawn away at the point of origin, but is attended with some disadvantage from the difficulty of controlling the sources from which the supplies of fresh air are drawn, since it rushes in through all available openings. Provision may, however, be made at suitable points for free admission of pure air, which may be warmed, cooled, moistened, washed, or screened, as it enters. When propulsion is adopted, the air is taken from one source only, and, being more under control, is more readily subjected to such heating or other treatment as may be needed.

The advantages of artificial ventilation are its constancy under all conditions and the facilities which it affords for regulating the source and amount of fresh air, and the preparatory treatment as to temperature, moisture, and purification. Natural ventilation is, of course, less costly, but is inconveniently subject to atmospheric conditions, and is inadequate for theatres, schools, and other large crowded buildings. The following averages are based upon a number of observations (18 to 39) in schools by Carnelley, Haldane, and Anderson.

	Natural Ventilation.	Mechanical Ventilation.
Per cent. of windows open . .	22	3
Cubic feet of air space, per head .	168	164
Temperature	55·6° F.	62° F.
Carbonic acid (per 1,000 vols.) .	18·6	12·3
Organic matter (vols. of oxygen required *per million* vols. of air)	16·2	10·1
Microbes (per litre)	152	16·6

The difference is still more striking if only the excess over the impurities present in outside air is taken into consideration. It was found that mechanical ventilation kept the composition of the air fairly constant in all parts of the room, while natural ventilation often allowed of local stagnation.

In an ordinary room the chimney is the most important outlet when a fire is burning, air passing up with an average velocity of 4 or 5 feet per second. In the absence of a fire the chimney still acts in some degree as an upcast, and ought on no account to be closed, unless a downward current establishes itself temporarily, and causes annoyance by its sooty smell.

Warming is closely connected with ventilation. The principal methods in use may be classed as open fires, closed fires and stoves, hot air, and pipes containing hot water or steam. Some of these heat the room by radiation, warming the surfaces while leaving the air in it cool; some by convection, warming the air of the room and thus making it drier; some in both ways. Again, some (*e.g.* open fires) carry off large volumes of air besides their own products of combustion, some (*e.g.* gas or other stoves) only little; some (hot pipes) none at all; while others, and especially fender stoves, do not ventilate but add to the impurity of the air.

Ordinary **open fires** are extravagant in regard to fuel, and it is estimated that only about one-eighth part of the potential heat is utilised in warming the room, the rest being lost in unconsumed smoke and cinder, and in the hot gases passing up the chimney. The heating effect is very unequal in different parts of the room, being chiefly confined to the vicinity of the grate, and cold currents pass along the floor. They are, however, most effective ventilators, and present a more cheerful appearance than stoves or hot pipes.

The principal practical points in regard to the

construction of open fire grates are summarised by Teale as follows:—(1) use as much firebrick and as little iron as possible; (2) the back and sides should be made of firebrick; (3) the back of the fire-place should lean over the fire, the "throat" of the chimney should be contracted; (4) the bottom of the fire should be deep from before back; (5) the slits in the bottom grating should be narrow; (6) the bars in front should be narrow; (7) the space beneath the fire should he closed in front by a close-fitting iron shield, or "economiser," thus excluding cold air almost completely from the bottom of the fire, so that the fuel as it sinks is entirely burnt up, leaving only a fine ash, which drops into the space beneath. Another means of preventing waste of fuel is to make the bottom of the grate of solid fire-clay, as in the various "slow combustion" grates; and the same principle may be applied to ordinary grates by laying an iron plate upon the bars at the bottom of the grate.

Coke is the residue, consisting almost entirely of carbon and mineral ash, left in the retorts when all the combustible gases have been driven off by heat in the process of gas-making. It is smokeless and less costly than coal, but it is difficult to light, and makes a dull fire. The prevention of smoke, and the complete utilisation of the gases and other products obtainable from coal by distillation, are important public advantages.

Gas-fires have much of the bright and attractive appearance of open fires. The gas is mingled with a considerable volume of air before ignition, as in a Bunsen burner, and the intensely hot but non-luminous flame impinges upon pieces of asbestos or iron, which become red or white-hot, giving out light and heat. Simpler forms are also made with ordinary luminous burners, the light and heat from which are thrown forward by

metal reflectors; oil-stoves are made on the same principle. In any case an adequate flue to carry off the fumes is essential.* A gas-fire burns from ten to twenty, or more, cubic feet per hour. It is economical and cleanly in use, creates no smoke, and can be lighted, extinguished, or regulated in a moment. Ventilating gas-stoves are made, but the ordinary gas-fire, unless it be composed of incandescent fragments of asbestos in an open grate, is less effectual than an open fire in promoting ventilation. If the flue is too small, as is very often the case, the air becomes dry and oppressive, and there is risk of carbonic oxide escaping.

Stoves for coal and coke, as used in England, are commonly made of cast iron, the smoke and products of combustion being conducted by an iron flue to the chimney, or to the outside air. The fire may be more or less open, or hidden from sight, but in any case the waste of heat is less than in ordinary fire-places, the sides of the stove and also the flue contributing to the heating power. As a means of extraction of vitiated air a stove is inferior to the ordinary open fire, although there is no difficulty in utilising the hot flue for the purpose of producing an up-current in a chimney. There are also many forms of ventilating stoves, fresh air being brought in through special pipes, which in their course are exposed to the heat of the stove; in the "Calorigen" a coil of the fresh air inlet pipe is placed inside the stove. Stoves tend to make the air hot and dry, an objection which may be met by placing vessels of water upon them. A more serious difficulty is a burnt smell which is apt to result from their use, and a tendency to give off carbonic oxide,

* The consumption of gas is relatively large and not limited to hours of darkness. *Besides CO_2, sulphur acids* and traces of carbonic oxide are given off. *The condensation of fumes,* which is claimed for some gas fires, *is at best only partial.*

the source of which is a matter of some doubt. It has been attributed to oxidation of the organic matter in the air by contact with the heated iron, this being also assigned as the cause of the burnt smell. Oxidation of the carbon in the cast iron is another suggested explanation, and it has been found experimentally that red-hot cast iron is pervious to carbonic oxide, and even reduces carbonic acid to carbonic oxide, so that the gas found in the room may originate in the fire itself. Wrought iron offers far greater resistance. The joints, both of the stove and the flue, should be made strong and air-tight, and in order to minimise the risk of giving off carbonic oxide, it is desirable to line the stove with fire-clay, to coat it with silicate, or to use earthenware or wrought iron in place of cast iron. Stoves can only be approved from a sanitary point of view if they (*a*) are provided with proper chimneys; (*b*) are of such a pattern that they cannot become red-hot, or otherwise contaminate the air; and (*c*) are supplied with fresh air directly from the outside.

Hot air is advocated by some authorities as the best mode of warming houses, as well as public buildings. This may be done upon the large scale by warming the fresh air in the basement, and conveying it thence to all parts of the house along the passages or by special channels. The same end is attained in some degree by placing a stove or fire-place in the hall. Warm air may be supplied to single rooms by the ventilating grates or stoves already referred to, or by allowing the fresh air to enter through a coil of hot pipes. The air can be moistened, and, if need be, purified by filtration or washing. Warming can also be effected by means of **hot water or steam** circulating in a system of closed pipes. The pipes may be carried round one or more sides of a room, *near the* floor, either open, or concealed behind a

skirting-board. Several turns or coils may be used at points where more heating power is required, and it is convenient to warm the fresh-air at the inlets by the same means.

Hot water is usually employed for heating purposes at a temperature below 212° Fahr. The circulation is dependent upon the water being hotter, and therefore lighter, in the tube through which it leaves the boiler than in that which brings it back. Hence the boiler is placed at the lowest point, and the centrifugal and centripetal pipes are respectively connected with the top and bottom of the boiler. A feeding cistern, and vents for the escape of air and steam, are provided at the highest point. About twelve feet of four-inch iron pipe are allowed for every thousand cubic feet of air-space to be warmed. The system should be so planned with valves and connecting pipes as to allow of "short-circuiting," so that the heat may be turned on or cut off from any part at will.

Hot water may also be used under pressure at temperatures considerably exceeding 212° Fahr., on Perkins' system. Strong half-inch iron pipes are used, and instead of a boiler, part of the pipe is carried through the fire. Steam may be used at high or low pressure in like manner.

Inspection of houses.—The following schedule includes the principal points that may require attention. The headings are numerous, but are meant to be chiefly suggestive, so that no important detail may be overlooked. A very few notes will often suffice in practice. As in all other investigations, it is wise to make explicit written notes on the spot, and to insert negative as well as positive results of inspection.

Address.
Occupier.
Owner.—Name and address.

Site.—Elevation, aspect, slope. Proximity to hills, valleys, watercourses. Nature of soil. Dryness.

Surroundings.—House detached, semi-detached, in a row, back to back. Access of light and air. Obstruction by trees, high grounds, or other buildings. Open space at front, back, sides [stating area]. Proximity [stating distance in feet] of stables, cow-sheds, pig-styes, manure heaps, foul ditches, stagnant water, offensive accumulation, offensive trades, or other sources of effluvia.

Yard and Outbuildings.—Condition as to cleanliness, paving, drainage, area, closets, workshops.

Foundations.—Damp-proof course, dry area, banking of soil against walls. Dryness of basement. Exclusion of ground-air. Ventilation of space beneath ground floor.

Walls.—Materials, thickness. Party walls carried up to roof? Dilapidations. Evidence of damp at any part; probable source of such damp.

Roof.—Construction. Soundness.

Floors, Staircases, Windows, Doors, Ceilings.—Soundness.

Rooms.—Number on each storey, including basement.

Length, breadth, and height. Windows. Total window-space. Space made to open. Opening top and bottom? Other means of ventilation. Maintenance of ventilation. Chimney	of each room.*

Heating Arrangements.—Grates, stoves, flues. Hot water or steam system. Boilers, bath-geysers.

Drainage—

Sink wastes Bath wastes Lavatory wastes Floor gullies	Construction and course of waste-pipes. Description and efficiency of traps. Disconnection.

Soil-pipes. Construction, dimensions, position, course, ventilation.

Gullies. Construction and trapping.

Gutters around eaves. Efficiency.

Rain-pipes. Course, trapping, disconnection, destination. Leakage?

House drains. Course, construction, dimensions, grad-

**As regards sleeping-rooms in basement*, or "underground rooms," certain further details are necessary, namely, depth of floor below level of adjoining street; height of room; height of ceiling above footpath or *nearest* ground adjoining; width, depth, and lateral extent of area in *front; depth of drain* below floor; position of window in respect to steps *(if any) bridging* across open area; the conditions as to letting and *occupancy.*

ients, ventilation, means of access (inspection chamber), disconnection from sewer (interceptor). Flushing, cleanliness. Soundness, as tested by smoke, chemical test, or water. Drains under basement.

Cesspool (if any).—Position, construction, dimensions, ventilation, overflow, watertight.

Sanitary Conveniences.—Number, position, cleanliness, lighting, ventilation. If outdoor, note distance from nearest door or window. If more than one house using same closet, note the number. State also number of occupants.

W.C., trough-closet, slop-closet, hand-flushed closet. Kind of apparatus, efficiency, source of water-supply, sufficiency of flush.

Pail-, pan-, tub-, or box-closet. Size of receptacle, material, floor-level, means of access, with or without ashes or other admixture.

Privy-midden, privy with cesspit, earth-closet. Dimensions of receptacle, relation of floor to ground-level, materials, watertight, covered, arrangement for applying ashes or earth to excreta. Connected with sewer?

Household Refuse.—Means of storage. Position.

Scavenging.—Mode, frequency, and efficiency of removal of excreta and household refuse. By whom performed.

Water Supply.—Public or private, from mains (by tap or stand-pipe), spring, stream, canal, dip-trough, well, rain-water cistern; distance from house, constancy, sufficiency, purity. Note any obvious risk of pollution. If from well, note depth, construction, lining, cover; distance in feet of nearest possible source of pollution, or filth accumulation of any kind. If from cistern, note position, construction, cover, cleanliness, connection with W.C., discharge of overflow pipe.

Cleanliness of Premises.—Light. Ventilation. Cleanliness.

Animals kept.—Description. Number. Where kept. Nuisance resulting.

Inmates.—Number of residents. Age, sex, occupation of each. Number of families; distinguishing tenement occupied by each.

Number sleeping in each room, if there is suspicion of overcrowding. Number sleeping in basement.

Houses vary as to need of inspection according to class and kind. *Private houses* occupied by one *family presumably* belong to persons of such social

position and habits that the house requires but little enforcement of sanitation. *Houses let in lodgings*, or tenement houses, on the contrary, require a good deal of supervision. Houses of this nature are such as are let out to separate families, living each in a separate occupancy of one or more rooms. There is no common kitchen or common dormitory. Houses let in lodgings are usually placed under special bye-laws under which they are registered, and controlled in respect of occupancy, overcrowding, sanitation, periodical cleansing, etc. Not unfrequently these houses were built for use as private dwellings, and have become sublet without structural alteration. Under the Customs and Inland Revenue Act of 1890 the landlord of tenement dwellings let at rents not exceeding 7s. 6d. per week may be exempted from inhabited house duty if the medical officer of health of the district certifies the house as sanitarily fit for the purposes to which it is put. By that Act, and by bye-laws for houses let in lodgings, a certain amount of control is exercised.

Common Lodging Houses are lodging houses pure and simple, with living-room, kitchen and dormitory, open to use by all the lodgers, who are not members of the same family, but are isolated persons, finding it convenient to lodge together. *Artisans' dwellings*, such as those under the Guinness Trust, the Peabody Trust, etc., are blocks of "model" dwellings, not different in principle, but better in equipment than houses let in lodgings. *Stable dwellings* are tenements over stables in "mews." They are objectionable, owing to the occurrence of effluvia arising from stables, manure, etc., and they generally have other defects. *Underground dwellings* are tenements limited to basement rooms, the ceiling of which is not *higher than the* level of the street.

CHAPTER VII.

SCHOOLS.

The general principles as to site, surroundings, construction, and drainage are, of course, the same for schools as for most other buildings.

Dimensions. The Board of Education recommend that no school should ordinarily be built to accommodate more than 1,000 to 1,200 children in three departments, and no single department to accommodate more than 400 children. For departments of this size the most suitable plan is that of a central hall ($3\frac{1}{2}$–4 ft. floor space per scholar) with (about 7) class-rooms grouped round it. Smaller departments may have class-rooms opening from a corridor. For small schools a large room with one or more class-rooms will be sufficient. There should always be at least one class-room, in addition to the central hall, except in special cases.

Where the site is sufficiently large, open and fairly level, the most economical plan is that of a school on a single floor, and this is preferable on educational grounds. In any case a school building should, preferably, not be on more than two floors.

For older scholars the Board prescribe a minimum of 10 sq. ft. floor space per scholar. For infants 9 sq. feet, unless there is no corridor or central hall, in which case more than 9 sq. ft. is required; but 120–200 cubic ft. of air space per pupil and 15 sq. ft. of floor space is now generally regarded as desirable. The Board has fixed a standard for higher elementary schools of 16 sq. ft. per scholar if single desks be used, and 13 *sq. ft. for dual* desks, and for secondary schools *18 sq. ft.*

Lighting.—Every part and corner of a school should be fully lighted, and, as far as possible, from the left side of the scholars; all other windows in class-rooms should be regarded as supplementary or for ventilation. Where left light is impossible, right light is next best; direct front light is in no circumstances approved.

Windows should never be provided for the sake merely of external effect. All kinds of glazing which diminish the light and are troublesome to keep clean and in repair must be avoided. A large portion of each window should be made to open for ventilation and for cleaning. The sills of the main lighting windows should be not more than 4 feet above the floor; the tops of the windows should as a rule reach nearly to the ceiling; the upper portion may be made to swing. The ordinary rules respecting hospitals should here be remembered. Large spaces between the window heads and ceiling collect foul air.

Skylights are objectionable in schoolrooms or class-rooms. They may be allowed in central halls having ridge or apex ventilation. The colouring of the walls, ceilings, and fittings, and the size and position of the windows, are especially important in their bearing on the eyesight of the children.

Natural Ventilation is rarely sufficient to maintain the purity of the air in schools, and artificial means, coupled, when necessary, with filtration, warming, and moistening, are therefore desirable though not always attainable in practice. Kerr suggests a limit of 10 parts of CO_2 per 10,000. About 2,000 cubic feet of fresh air per head per hour is required, and it should enter the room at a rate not exceeding 5 feet per second. This is best obtained, as pointed out by Carnelley and Haldane, by using large low-pressure fans, running at low speeds. It is also desirable to have exhaust as well as plenum fans, so that the

air pressure in the rooms may be kept low and short circuiting avoided. Whatever method of ventilation is used, the design should be such as to allow large volumes of air to pass through the buildings from side to side when the windows are open. The window area should be not less than $\frac{1}{10}$ of the floor area and may with advantage be $\frac{1}{5}$. When the windows are suitably designed, carried to the ceiling, easily opened at the top, and intelligently used in connection with two or more warm outlet flues or separate air chimneys from the ceiling and floor level to above the roof, and there are also large open ventilating fire-grates, stoves and radiators, by which warmed fresh air is admitted, class-rooms can be both warmed and ventilated adequately and economically.

Desks. The edge of the desk should be vertically, or nearly so, over the front edge of the seat, and about the height of the scholar's elbow. The seat should be at least 9 inches wide, and about the height of the knee. The desk should slope (15°), and the seat be provided with a back: it is desirable to provide for a little horizontal adjustment of either the seat or the desk, so that they may be slightly separated for writing, and brought together for reading. If a bench is used, 18 inches should be allowed to each pupil

A simple arrangement contriving the advantages of dual desks without the disadvantages is a continuous desk of half a dozen places with single pedestal chairs (the "Sheffield System"). Many schools in the north of England are now fitted with this kind of desk. It is supported on two plain pedestals screwed to the floor. Each seat has a back, and stands on a single pedestal. The advantages are that the seats are isolated, each child is accessible, and can stand by its seat in its place for drill, etc., and schoolrooms cannot be overcrowded as with dual seats or forms. Each seat occupies about 1,000 square-

inches of space. Cleaning is much simplified with these seats and desks.

Playground.—The surfaces of the playground should be smooth without being slippery, and formed of materials such as asphalt or granolithic cement, which do not form dust. They should be durable and well drained. Some authorities recommend tar-paving. Gravel, cinder-ashes, shingle, and loose materials are unsuitable. A certain portion should be covered-in for use in wet weather. The whole playground should be open to the sun, and the school site should be of a size giving at least a quarter of an acre to 250 children, and the playground at least 30 square feet per child.

Cloak-rooms other than passages should be provided where damp garments can be dried. Cloak hooks should be fixed 12 inches apart, and gangways between rows of hooks should be not less than 4 feet wide.

Water supply.—All schools should be provided with an adequate supply of wholesome drinking water. If such supply cannot be obtained from the public mains, care must be taken to ascertain that the supply proposed is adequate, is of suitable character, and not liable to pollution.

The pipes should be so laid as to be protected from frost, and so that in the event of their becoming unsound the water will not be liable to become fouled, or to escape. There should be no direct communication between any pipe or cistern from which water is drawn for domestic purposes, and any water closet or urinal.

All water closets and urinals should be provided with proper service cisterns, affording adequate flush. Any cistern should be watertight, covered and ventilated, and so placed that the interior may be readily inspected and cleansed.

Closets.—Separate closets are required for boys and girls, and there should be at least one for

every 15 to 25 girls and 25 to 40 boys. They should be disconnected from the school proper by a well-ventilated lobby or covered way. Flush-closets are best adapted for the purpose in some ways, and trough-closets are used in many schools. But, probably, the time has come for schools to be supplied with a sufficient number of some simple form of wash-down closet with separate water waste preventer cisterns or, if necessary, flushing apparatus for half a-dozen at one time. No dry system works well in schools, as the admixture of ashes is insufficient for dryness and deodorisation. It is, of course, possible and necessary to make pails, earth-closets, or even privies serve the purpose in rural districts, but only by constant supervision and far more frequent cleansing and scavenging than are usually available can they be prevented from becoming a serious nuisance in schools. They should be situated at least 30 feet from the school premises. Accumulations from school closets were the means of spreading disease, by pollution of the drinking water, in the typhoid outbreak in the villages of Eldesborough and Eaton Bray in 1904. Urinals, in proportion of 8 feet for 100 boys, should be properly constructed of smooth non-absorbent material, and should always have a sufficient water supply.

Schools and infectious diseases.—The following Memorandum was issued by the **L.G.B.** in August, 1904 :—

[1.] "respecting school-closure and exclusion from school as precautions against infection, with a view to indicate the best means of preventing the spread of disease by school children among their fellows, while avoiding any unnecessary interruption of the work of education."

2. In the Code of Regulations issued by the Board of Education in 1904, the following Article (Art. 57) prescribes, as one of the general conditions required to be fulfilled by a *Public Elementary School in order to obtain an annual Parliamentary grant, that*—

"If the **S.A.** of the District in which the school is situated, or any two members thereof, acting on the advice of the **M.O.H.**, require either the closure of the school or the exclusion of certain children for a specified time, with a view to preventing the spread of disease or any danger to health likely to arise from the condition of the school, such requirement must at once be complied with, but after compliance appeal may be made to the Board (of Education) if the requirement is considered unreasonable."

Article 45 (b) prescribes that "if there has been a closure under medical authority, or for any other unavoidable cause, the number of meetings required [400 a year] is proportionately decreased."

(The "medical authority" referred to in this article is not necessarily that of the **M.O.H.**)*

3. The diseases for the prevention of which school closure, or the exclusion of particular children, will be required are principally those which spread by infection directly from person to person, such as diphtheria,† scarlet fever, measles, whooping-cough, epidemic influenza, small-pox,‡ and rötheln. More rarely, the same question arises in connection with enteric fever and diarrhœal diseases, which spread not so much by direct infection from person to person as indirectly through the agency of local conditions, such as infected school privies.

4. It will be seen that Article 57 quoted above confers upon sanitary authorities an alternative power with respect to public elementary schools. (A) To cause particular scholars to be for a specified time excluded from attendance, or (B) to require the school to be closed for a specified time.

5.—*A. First, as to exclusion from school of particular scholars.*—Here it will be convenient to consider the circumstances under which the requirements of the public health will be satisfied by the less severe measure of the exclusion from school of particular children.

(*a.*) It may be laid down as a universal principle that all children suffering from any dangerous infectious disorder (*i.e.*

* The manager of a school may close, under the advice of a duly qualified medical practitioner, and then claim exception from the rule requiring 400 attendances, and they must close under notice from the **S.A.** on the advice of the **M.O.H.**

† There are special considerations that have to be borne in mind in regard to diphtheria. Conditions of school aggregation alone seem occasionally to intensify the virulence of the type of this disease. (*See* chapter xiv.)

‡ Small-pox has only a small incidence upon children of school age, under ordinary conditions of infant vaccination, but in districts where vaccination is now neglected it has occasionally been found necessary to close schools on account of prevalence of small-pox.

of a nature dangerous to some of the persons attacked by it, however mild in other cases) should be excluded from school until there is reason to believe that they have ceased to be in an infectious condition (*see* s. 126 P. H. Act. 1875).

(*b.*) Furthermore, as it is rarely possible to provide effectual separation of the sick from the healthy within the homes of children of the class attending public elementary schools, it must commonly be necessary that all children of an infected household should be excluded from school, first, because otherwise such children might attend school while suffering from the disease in a latent form, or at an unrecognised stage, and, secondly, because it is known that infection may attach itself to, and be conveyed by, the clothes of a person living in an infected atmosphere, even though the person himself remain unaffected. The same considerations will sometimes make it desirable to prohibit the attendance at school of all children from a particular street or hamlet.

> In the case of infectious diseases involving little or no danger to life, such as mumps or skin diseases, school interests may be more particularly considered. In such case, however, it will usually be well for the **M.O.H.** to advise the managers to prohibit the attendance of every child while in an infectious state.

6. *B. Secondly, as to the closing of schools.* This, by more seriously interfering with the educational work of a district, is a much more grave step for a **S.A.** to take than to direct the exclusion of particular scholars. It is a measure that seldom ought to be enforced, except under circumstances involving imminent risk of an epidemic, nor even then as a matter of routine, nor unless there be a clear prospect of preventing the propagation of disease such as could not be looked for from less comprehensive action.

> The mere fact that in an epidemic many of the sufferers are school children does not necessarily show that the disease was caught at school, but the school may with probability be regarded as spreading infection if in a large majority of households attacked the first case be a child attending school, and with still greater probability if a number of children living at a distance from one another, and with no circumstances in common, except that they attend the same school, should be simultaneously attacked, and if it can be ascertained that a child or teacher in an infectious state has actually been attending the school.

7. By Article 186 of the Board's Order of 23rd March, 1891, the **M.O.H.** on the occasion of an outbreak of dangerous

infectious disease is to advise the persons competent to act as to the measures to be taken to prevent the extension of the disease. If, therefore, he finds that the children of infected households are attending school, he should send notice of the fact to the schoolmaster, and give such advice as appears to him to be necessary with regard to the exclusion of the children from school, and as to the time for which such exclusion should continue.*

Where the number of children to be excluded is small, and the schoolmaster acts on the advice of the M.O.H., it may not be necessary to take formal action under Article 57 of the code; but where the number of children whom it is desirable to exclude from school is such as is likely seriously to diminish the average attendance, or where the advice of the M.O.H. is not followed, and there is danger of the disease spreading by means of the school, notice for the exclusion of the children in question should be made in accordance with the requirements of Article 57.

The attention of school attendance officers and of schoolmasters should also be drawn to the following considerations. Frequently they themselves will obtain the earliest information of the occurrence of infectious disease among scholars, and it is most desirable that such officer or master should without delay communicate the facts to the M.O.H. Absence of any child from school on the plea that it is suffering under one of the before-mentioned diseases, and absence of several children of one family from school at the same time, no matter what name be given to the complaint that keeps them at home, should be reported to the health officer. In practice it has been found that this notification of absentees has materially aided the local health officer in taking measures for the suppression of infectious disease, to the advantage alike of the district and of the school. Furthermore, schoolmasters may properly be asked to take note, especially when an epidemic threatens or is present, of symptoms occurring in any of their scholars that may indicate the commencement of disease, febrile in nature. Besides heat of skin, such symptoms are shivering, headache, and languor, especially if commencing suddenly, vomiting, rashes on the skin, and sore throat. When scarlet fever

* It is well always to send a second notice when the infection is at an end and the quarantine is terminated. Copies of these notices may with *advantage be sent to* the school authorities, in order that the school *attendance officer may* not in the meantime press the parents to send the *children to school.*

or diphtheria is about, every trace of sore throat should be looked upon as suspicious. In any case where such symptoms are observed, the safest course will be to exclude the child from school until assurance can be had that it may attend school without harm to itself or danger to other scholars.

8. As regards duration of exclusion from school of particular children, the time to be specified will vary in different diseases and different cases, and in this matter the sanitary authority will doubtless be guided by the advice of their M.O.H.

> Medical officers of health, having to specify a time during which any scholars are to be excluded from attendance at any school, should have regard as far as practicable to the circumstances of the particular scholars suffering from infectious disease or living in infected households. Not only the nature of the infection and the length of illness, but the environments of the individual as affecting the retention of infection, will deserve consideration. The period of exclusion, for example, will need to be different according to the conditions of a patient's lodgment, according to the sufficiency of the separation that can be effected between a patient and excluded scholars, and according to the opportunities of effectual disinfection that can be afforded to the household. Thus a hard and fast rule, such as has been laid down in some districts where scarlatina has been present, that no child shall go to school from an infected house for three months after the disease has begun in that house, is not to be commended. It is indeed possible that under the circumstances of a particular household, a child convalescent from scarlatina or living in the same house with convalescents should not in the interests of other children be permitted to return to school until after so long a period as this; but the same ought not to be assumed of all households in the district that may be invaded by scarlatina. The better plan would be for the S.A. to secure, during a shorter period, the exclusion of individual sick persons and their housemates from school; and when that period is about to expire to cause fresh inquiry to be made as to the expediency of further exclusion, and, if found requisite in particular cases, to cause fresh notice to be given to the school managers.

9. In deciding whether an outbreak of infectious disease among *children of school age* may be best combated by closing *the school, or whether it* will suffice to exclude the children of

infected households, the two most important points to be considered are:—

(*a*) The completeness and promptness of the information received by the officers of the S.A. respecting the occurrence of infectious cases.

(*b*) The opportunities which exist for intercourse between the children of different households elsewhere than at school.

10. (*a*) The more prompt and full the knowledge of cases of infectious disease that the S.A. are able to obtain, the better will be the prospect of checking such disease by keeping away from school the children of infected households, and the less will be the necessity for closing schools.* If the cases be few in number, and their origin known, the exclusion from school of the children of infected households will probably suffice, but this measure will fail where there are many undiscovered or unrecognised cases, or where the known centres of infection are very numerous.

Commonly, the failure of carefully considered measures of exclusion to stay the spread of an epidemic which shows a special incidence upon school children, may be regarded as pointing to the continued attendance at school of children with the prevalent disease in a mild or unrecognised form, and a strong case will appear for the closing of schools.

If by reason of the absence or exclusion of a considerable number of children the attendance at a school be greatly reduced, it may be found better to close it altogether. This is especially apt to occur in the case of epidemics of measles, a disease which is very infectious in the early stages, before the characteristic rash has appeared, and while the symptoms resemble those of a common cold.

11. (*b*) The second material consideration, in deciding as to the desirability of closing schools during the prevalence of infectious disease, is the amount of opportunity for intercommunication between the members of different households elsewhere than at school. In sparsely populated rural districts, where the children of different households, or of separate hamlets, rarely meet except at, or on their way to, the village school, the closing of the school is likely to be effectual in checking the spread of disease. It is less likely to be useful in a town or compact village (particularly where houses are sub-let and yards are in common), where the children of different households when not at school spend their time in playing together, and often run in and out of each other's houses. But it must be remembered that children when at

* *Information obtainable* under the Infectious Diseases (Notification) *Act, 1889, will be specially* useful in this direction.

play out of doors are brought into much less close association with each other than when at school.

In rural districts, where epidemic diseases are less frequently prevalent, school closing may be required as an exceptional measure to meet an exceptional state of things. As regards more populous places, it must not be forgotten that if schools were to be closed whenever an infectious disease was prevalent, there are many places where schools would hardly ever be open.

It will sometimes be necessary to close school for a day or two to allow of the rectification of sanitary defects of a nature to extend disease, or in order that the school may be disinfected or purified. It has happened that infectious sickness in the master's family has forbidden the attendance of scholars. These more temporary and occasional closures of schools are contemplated in the Education Code, and are to be regarded as having a real importance of their own.

12. In places where there are several public elementary schools, if an outbreak of infectious disease be confined to the scholars of one particular school, it may be sufficient to close that school only. But where different schools have all appeared to aid in the spread of disease (though perhaps to an unequal extent), the **S.A.** may consider it advisable that all should be closed lest children in an infectious state who previously attended the schools that are closed should be sent to others that might remain open.

It must be remembered that sanitary authorities have no power in respect of Sunday schools, or other private schools: except in so far as these may contravene s. 91[5], s. 126, or other provision of the P.H. Act, 1875; but it will often be expedient to invite the co-operation of managers of such schools in efforts for securing the public health. Experience shows that they are usually ready to defer to the representations of the authority responsible for the public health of the district.

13. The **M.O.H.** has not power to order the closing of a school; his function in this respect is advisory only. Reports of **M.O.H.** to sanitary authorities, advising the closure of a school or schools in any district, are to be treated as "special' reports within the meaning of the General Order of the **L.G.B.** of March 23rd, 1891, and copies of them are required by Art. 18 (15) and (16) of that Order to be sent to the Board, and to the County Council. These reports should state the grounds upon which the **M.O.H.** advocates the

closure of the school or schools in preference to the exclusion of particular scholars.

14. All notices of the sanitary authority for the closing of Public Elementary Schools should be addressed in writing to the Managers, and should state the grounds on which the closing is deemed necessary.

All such notices shall specify a definite time during which the school is to remain closed; this should be as short a period as can be regarded as sufficing on sanitary grounds, since a second notice may be given before the expiration of the first, if it should be found necessary to postpone the re-opening of a school. The Managers of schools, after complying with the requirements of the S.A., have the right of appeal to the Board of Education, if they consider any notice to be unreasonable.

The following periods of exclusion are advised by the Association of Medical Officers of Schools :—

Disease.	*Quarantine* to be required after last exposure to infection.	Earliest date of return to School after an attack.
Small-pox ..	16 days	When all scabs have fallen off.
Chicken-pox ..	20 ,,	Ditto.
Scarlet fever ..	10 ,,	Six weeks, and then only if no desquamation, sore throat, or discharge from ear, &c.
Diphtheria ..	14 ,,	Four weeks, if convalescence be complete, and no sore throat, albuminuria or discharges remain; and bacteriological examination of the throat is on two consecutive occasions negative.
Measles	16 ,,	Two weeks, if all desquamation and cough have ceased.
Whooping Cough ..	21 ,,	Five weeks from the commencement of the whooping, if the characteristic spasmodic cough and whooping have ceased. Earlier, if all cough be gone.
Rötheln ..	16 ,,	Two to three weeks, according to the nature of the case.
Mumps	21 ,,	Three weeks, if all swelling has subsided.

It is understood in all cases that thorough disinfection *is carried* out. As a further safeguard it is

desirable to insist upon a medical certificate of freedom from infection when a child returns to school after an infectious illness.

Typhus and enteric fever are not included in the list. They, of course, rarely require consideration. In either, three weeks may be adopted as the period of quarantine; and four weeks as the earliest date of return to school after an attack, if all symptoms have disappeared and convalescence is complete.

The duration of ringworm, ophthalmia, impetigo, and scabies is indefinite; and children suffering from any of these should be rigidly excluded until all trace of the disease has disappeared.

It is important that teachers should be acquainted with the early signs of infectious diseases, and should watch for them, especially if such diseases are prevalent in the neighbourhood, or if any of the children attending the school have been attacked. It is important, too, that the school authorities should co-operate with the **S.A.** in such matters, and should report cases of non-notifiable disease. Slight attacks may escape recognition until late (*e.g.* until the desquamation stage of scarlet fever), and multiple instances of sore throat should always be regarded with suspicion.

CHAPTER VIII.

HOSPITALS.

General Considerations.—All that has been said in respect of the site, surroundings, and construction of houses applies with still greater force to hospitals. Pure air and light are of especial importance in sick wards, that are occupied day and night. The site should be as dry and open as possible, not exposed to smoke or effluvium borne by wind, and not unduly sheltered by trees, buildings, or hills.

Wards.—Long wards should face east and west so as to admit sun on each side alternately, and if any deviation is necessary it should preferably be such as to give a south-east and north-west aspect (Thorne-Thorne). Single-storey hospitals are preferable, as affording the freest circulation of air. Each ward is then completely detached from the rest, and the absence of stairs is advantageous; but from motives of economy and convenience of concentration two or more storeys are usually built.

Small wards are inevitable in cottage hospitals, and, indeed, in all hospitals, since provision has to be made for the isolation of severe or infectious cases, and for the classification of patients according to sex, and sometimes according to disease. As a general proposition, however, large wards are more readily ventilated, warmed, and lighted, more economical in construction and management, and more convenient as regards nursing.

For long wards the width should be 24 to 30 feet, the height 13 to 14 feet, and the length such as to allow a cubic space per patient of at least 1,200 feet. Not less than 2,000 feet is considered necessary in a fever or lying-in hospital, or

for severe surgical cases. It is not permissible to obtain this space by increasing the height. As already explained, extreme height is of little utility as regards ventilation, and in hospitals it is essential to have plenty of floor space around each bed. For nursing purposes at least 90 square feet per bed is necessary, and more will be required if the ward is largely used for clinical teaching. Wherever there is any possibility of septic or other infection, as for example in surgical wards, lying in wards, and wards for infectious diseases, wide separation of beds is important. In such cases 12 feet of wall and 130 to 140 feet of floor space should be allowed. It is found that for convenience in nursing the number of beds in one ward should not exceed 32, and usually 24 or 28 would be preferable.

The beds are arranged with their heads to the wall, facing into the ward. Each bed should be placed between two adjoining windows, the space between the windows being not less than a foot wider than the bed. At most two beds may be allowed in one space, the interval between them being at least three feet. The intervals between the windows of a ward should be such as to allow of this arrangement. The windows should reach to within a foot of the ceiling.

All the surfaces should be impervious, smooth, and washable, and all ledges, crevices, and stagnant corners in which dust may lodge must be avoided. The floors may be paraffined or waxed, the walls lined with tiles or glazed brick, or Parian cement, or in the absence of such materials simply painted.

Heating and Ventilation.—The heating may be effected by open fire-places, or ventilating stoves, or both, and it is well to have in addition coils of steam or hot-water pipes with radiators in corridors. Ventilation must be provided for to the extent of at least 3,000 feet per head per hour, and it may be taken as a safe rule that the whole air of the ward ought to be changed thrice hourly, so that the hourly supply of fresh air should be three times the cubic capacity of the ward. Extraction is provided for by fire-places, stoves, windows opening at the top, Sheringham valves near the ceiling, chimney shafts, warm outlet flues, and in other ways. Special extraction

shafts, with inlets at or near the ceiling, are desirable. Such shafts may be carried up alongside, or surrounding the chimney or stove flue, so as to utilise the waste heat as a motive power ; or, independently of these, with a gas jet in the inlet to create an upward current. Some hospitals for infectious diseases have an extraction shaft upon a larger scale, the foul germ-laden air being made to pass through a gas furnace. Most, if not all, of the germs are no doubt destroyed in this way, and the rest are prevented from diffusing horizontally. This precaution was suggested by the Hospitals Commission, and is especially important in regard to smallpox hospitals, which have been shown to be capable, under certain conditions, of acting as foci from which infection spreads through the air.

It is desirable to make arrangements for warming the air passing into the wards. This may be done by means of ventilating fire-grates, ventilating stoves, or coils of hot pipes at the inlets. Windows, Sheringhams, and Tobins may suffice in warm weather. It is a common practice to place the inlets under beds, with the intention of avoiding draughts, and supplying the purest air close to the patients.

In the most approved plans a cross-ventilated corridor or ante-room leads from one corner of the ward to the water-closets and slop sinks, and the bath-room and lavatory are similarly placed at the adjoining corner. At the opposite end is a nurse's room with a window overlooking the ward.

Hospitals for infectious diseases.—Reference has already been made to the need for greater cubic space and ventilation in such hospitals, and to the importance of guarding against the tendency to aërial spread of infection in certain diseases. *The communication* with the outside has also to be *kept under strict* control. It is desirable that

"Isolation Hospitals" should themselves be isolated from other buildings, and even from thoroughfares, by reserving as wide an open space as possible. The boundary walls should be 6½ feet high. Each disease must be isolated separately, and if possible in separate blocks, not less than 40 feet apart, and the same distance from the boundary.* There should be no communication whatever between the different blocks, and the intercourse with the common administrative department should be as little as possible. As regards structure and arrangement of wards the standards named in respect of general hospitals apply. A special block containing at least two or three small wards is necessary for doubtful cases, or cases not received into the principal wards. The site should be high and airy, on dry gravelly soil, removed from buildings but not too exposed. It should not in any case be less than 2 acres in extent, and the number of patients per acre should not much exceed 20.

The essential parts of a hospital for infectious diseases are—

1. An administrative block, including rooms for the medical officers, matron, nurses, and servants; dispensary, kitchen, scullery, larder, and pantry; laundry, linen room, store-room, coal-cellar, bathrooms, closets, etc. etc.

2. Hospital blocks, namely, at least one for each disease to be isolated, and in each block at least two principal wards, one for each sex. Additional small wards for one or two beds are desirable. An "iso-

* The **L.G.B.** require (1902) that a small-pox hospital should not be so placed as to have within a quarter of a mile a hospital (whether for infectious diseases or not), a workhouse, or any similar establishment, or a population of 200 persons, or within half a mile a population of 600 persons, whether in one or more institutions or in dwelling houses. Even *when the above conditions are fulfilled a hospital must not be used at one and the same time for the reception of cases of small-pox and of any other kind of disease.*

lation block," consisting entirely of small wards, is most useful. Besides the wards, closets, sinks, and bathrooms, each block should contain a nurse's room, overlooking the ward, and so arranged as to serve as a scullery and ward-kitchen for minor cookery; linen-room, store-room, and coal-place. The nurse's sleeping-room must be away from the wards; it may be in the same block, but is more usually placed in the administrative block. Arrangements must be made for the patients from each block to take exercise in the grounds without coming into contact with each other. Small-pox hospitals should be entirely independent of those for other diseases.

3. Mortuary and post-mortem room; disinfecting room; stable and ambulance shed; porter's lodge, etc. etc. The drainage, water supply, and arrangements for heating need no special mention.

Cost.—The expenses to be incurred in respect of isolation hospitals are classified under the Isolation Hospitals Act as structural, establishment, and patients' expenses. We may first consider the capital or structural outlay. The great cost of permanent hospitals—rarely less than £200 and sometimes £400 per bed—has led to the substitution in many cases of temporary structures, more especially in the presence of an epidemic, when rapidity of construction is the first consideration (£20–£50 per bed). These may be tents or buildings of wood and galvanised or corrugated iron. Wooden hospitals are common, and can be run up in two or three weeks. The walls must be made double, and it has been found advisable to fill up the hollow with sawdust. The floors must be raised above the surface of the ground. The roof may be slated or tar-felted. The foundation required is generally a four-course brickwork with air-bricks and damp-proof course. The dimensions and arrangements can be made the same as in permanent buildings.

The same may be said of galvanised iron huts, which are often used for hospital purposes. Tents can be erected still more rapidly, upon a wooden floor raised above the level of the ground. The canvas should be double. Recently other forms of temporary hospitals have come into use, including those of Dœcker and Ducker types. Both of them are convenient in use, and can be erected at a few hours' notice. They consist of a stout waterproof material stretched upon wooden frames, so shaped and numbered that they can be speedily put together to form a complete and weather-proof hut, ready for the reception of patients. Willesden waterproof paper is also used for the construction of huts. Sometimes a composite construction has been preferred, with an administrative block of stone or brick, and pavilion wards of corrugated iron and wood costing about £120 a bed. It should be added that the **L.G.B.** does not as a rule sanction loans for the construction of temporary hospitals.

Their comparative cheapness and the rapidity with which they can be erected are important points in favour of temporary hospitals, but nevertheless their proper function is to supplement, and not to supersede, permanent buildings of brick or stone. They are less attractive in appearance than the latter, less comfortable, and more difficult to ventilate efficiently, and to keep warm or cool. True disinfection, such as to fit them for the reception of cases of different diseases, if not impossible, is at least less easy and less certain than in buildings with hard non-absorbent surfaces, free from pores and crevices. Their durability is far less than that of a permanent building, and an annually increasing outlay is needed in order to keep them in habitable repair. It is often claimed on behalf of temporary hospitals that no disinfection is necessary, since they can be burnt at the end of the epidemic, and renewed; but this plan, which would very soon prove more costly than the erection of permanent hospitals, has rarely, if ever, been put into practice. The economy in first cost is great, but is usually exaggerated. It must be remembered that the cost of erecting a permanent hospital, as

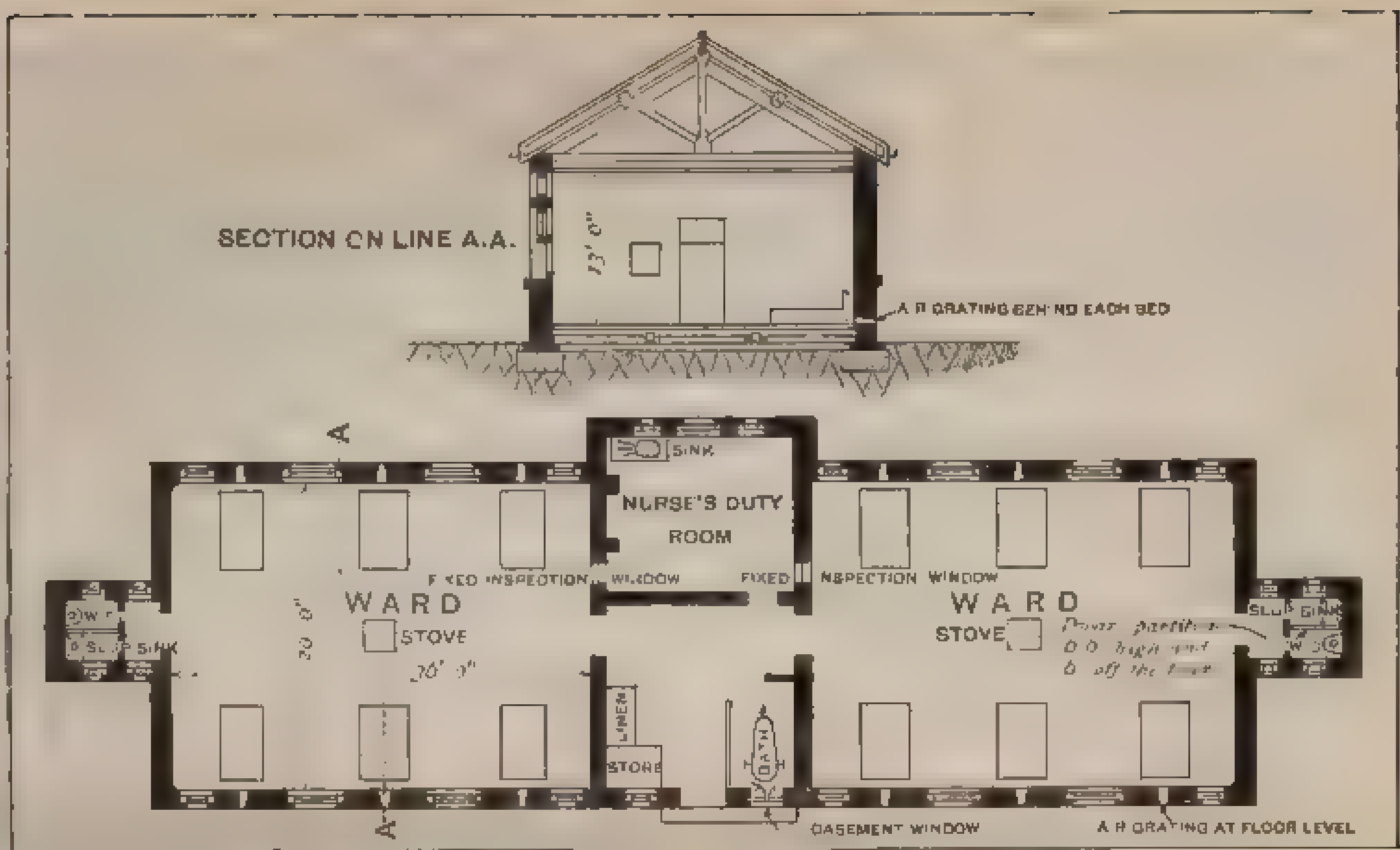

FIG. 8.—ISOLATION HOSPITALS.—PLAN OF A WARD PAVILION FOR TWELVE BEDS. (L.G.B. MODEL.)

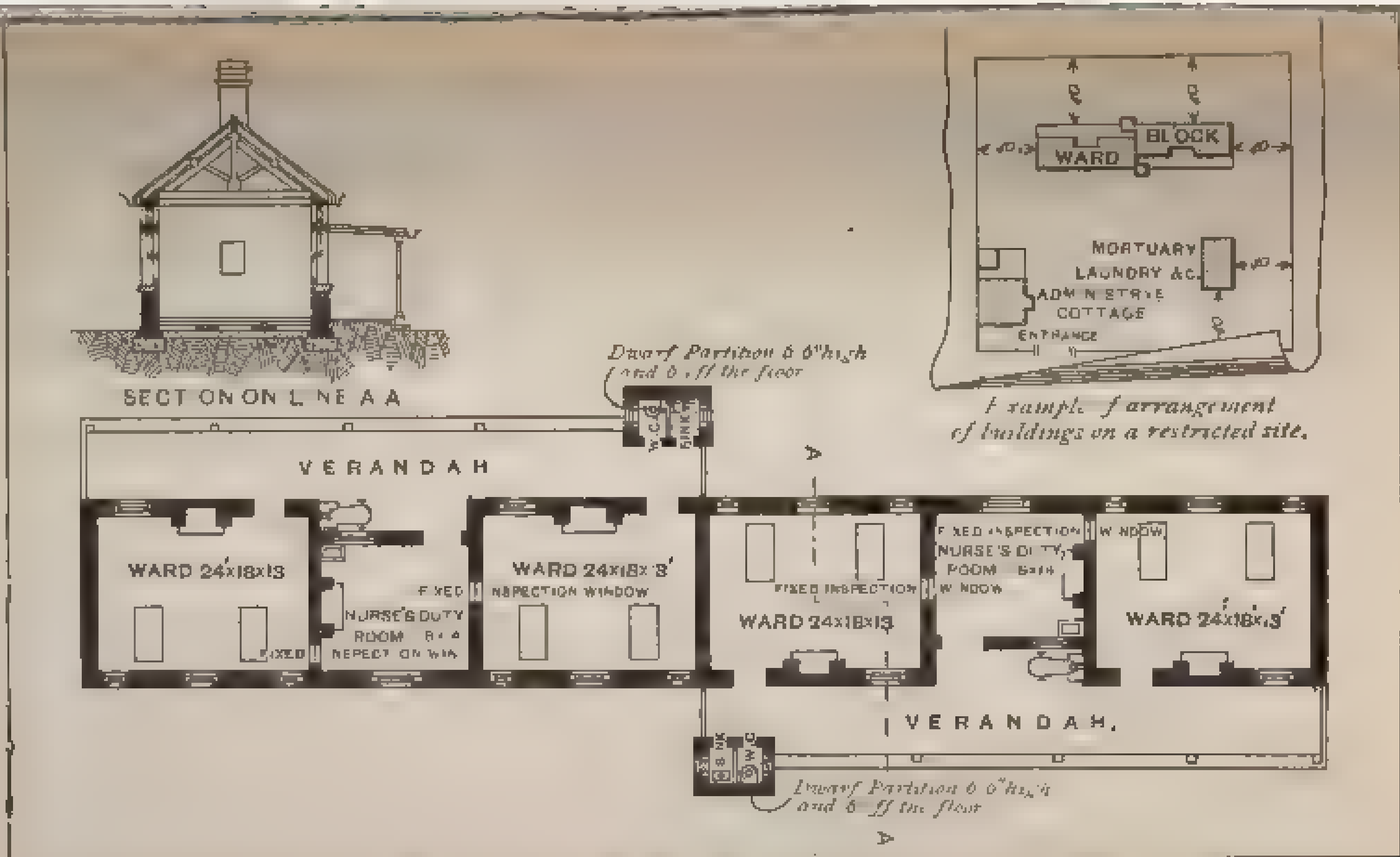

FIG. 9.—ISOLATION HOSPITALS.—PLAN OF AN "ISOLATION" BLOCK FOR EIGHT BEDS. (L.G.B. MODEL.)

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available for whatever disease is prevalent at the time. This can be done with safety and without difficulty if all the internal surfaces are impermeable. The wards, whatever the number of beds, must be sufficiently numerous to allow of the separation of the sexes wherever necessary, as well as the isolation of the several diseases one from another.

It is of the utmost importance, if isolation is attempted upon the large scale, to make the hospitals free, and this is only reasonable, since the public gain at least as much as the patient by his seclusion. The Sanitary Authority must not regard removal to hospital merely as a privilege sought by the patient and his friends, but as a concession on their part to the public safety. Any charges, however small and readily remitted, are deterrent in the very cases in which isolation is most needed. The revenue from patients' fees is at best a small fraction of the cost of maintenance, and the wholesale remission of them —without which the isolation of cases among the working classes is impracticable—has an appearance of charity which is naturally resented. An exception may be made in respect of the wealthy, who are willing to pay suitable fees for the use of private wards and special nurses.

Effect of hospital isolation.—The justification for isolation is based on the broad ground that certain diseases are infectious; that is, are readily transmissible from the sick to the healthy. Infected persons act therefore as foci of the disease, and where such persons are left in the midst of densely populated communities there is a greater tendency for the disease to spread than if such persons are isolated away from others. Although it may be possible to isolate almost any case of infectious disease in a large house, where all the requisite precautions can be rigidly maintained during the whole period of in-

fectiousness, it may be stated broadly that "home isolation" in smaller houses cannot be carried out in its entirety. In houses of the working class, for example, not one case of scarlet-fever in a hundred is, or can possibly be, properly isolated, during the whole period of still infectious convalescence, from the rest of the household, or even from the public. Medical supervision is usually withdrawn at the end of the acute stage of illness. Where satisfactory isolation can be provided at home, hospital isolation may be unnecessary, and if a hospital is badly administered, or there is overcrowding, such home isolation may even be preferable. There can be no doubt that the separation of the sick from the healthy has been invaluable in preventing the spread of disease, although instances are not rare in which hospital isolation has failed to give satisfactory results. This is not surprising when it is remembered that the isolation has often been partial, and the aggregation of infectious persons, more especially in times of epidemic pressure, carried too far. Many of the factors which determine epidemic and endemic prevalence of disease are still obscure, and it is only within the last 30 years that we have begun to appreciate the germ theory and what it means in actual practice. The hospital cases include many of the more virulent kind, and many from homes where means of isolation are most inadequate, and the removal of these cannot have failed to limit infection.

It has been contended, on the basis of certain local statistics of notification, isolation, and deaths, that isolation has failed materially to reduce the prevalence and fatality of scarlet-fever, and that the fatality has fallen more in towns which have not practised *hospital* isolation than in those which have; and this has been attributed to a "hospitalised strain" of scarlet-fever in the latter (*Millard*).

Hospital isolation has also been criticised on the ground of "return cases" of scarlet-fever; that is, secondary cases of the disease occurring in the same household after the return home of the primary patient from hospital. These have been found to be about 1·3 per cent. of the number discharged. Simpson has shown that 80 per cent. of such return cases are due to discharges from mucous membranes, such discharges being in all probability the carriers and not the causal agents of infection. Local and antiseptic treatment combined with transference to less infective wards before leaving are likely to be more effective in preventing return cases than long detention (*Simpson*).

In dealing statistically with this question it has to be remembered that we know nothing of what the figures would have been in the absence of hospital isolation, under the same conditions of increasing density of population. It is certainly true that scarlet-fever has not been eradicated, and the milder type of the disease now prevalent (as in Sydenham's time) adds to the risk of undetected cases, in which no question of isolation of any kind arises. The causal agent and the conditions which increase or lessen its virulence are also at present unknown.

Broadly, it may be said that any limitation of the spread of infection by personal contact must reduce the prevalence of the disease, and that therefore, if rightly managed, under proper conditions, hospital isolation is of direct and marked value in the reduction of scarlet-fever. The only alternative, the so-called home isolation, affords no prospect of safety. Further, it must not be forgotten that the isolation of cases of this disease in hospital prevents the infection of milk, houses, clothes, materials, etc., with the virus of the disease.

CHAPTER IX.

REMOVAL OF REFUSE.

The waste matter from households comprises (1) liquid refuse, including water used for washing, and slop-water; (2) ashes, and vegetable and animal refuse; and (3) excreta.

Drainage is necessary for dealing with the first, and some system of dry removal for the second. The excreta may be disposed of in conjunction with the former ("water-carriage"), or with the latter (privy-middens, ash-closets), or independently (earth-closets, privies, or pail-closets without admixture of ashes).

Drainage. A drain means any pipe used for the drainage of one building or premises. A sewer is a drain receiving the drainage of two or more premises. The former is vested in the owner, the latter in the **S.A.**

Drains are intended to remove from the house the liquid and much of the solid filth that is produced within it, and they should be so constructed that in no circumstances can their contents, liquid, solid, or gaseous, escape from them at any but the points specially provided for this purpose. This result is attained by the choice of proper materials for their construction and by sound workmanship, by trapping all inlets so as to prevent the egress of drain gases, and, lastly, by efficient ventilation at suitable points.

A **trap** in its simplest form is a mere bend in a pipe which retains water and thus prevents air from passing through it. For this purpose it is only necessary that the bend shall be sufficient to place some

portion of the upper surface of the pipe below the water level, the *seal* of the trap being the difference between the surface of the water and the depression at this point. Thus, in the diagram (Fig. 10), the seal is the water between *a* and *b*.

A water-seal alone will not always prevent the passage of gases and particulate matter through it. Gases in the drain can be absorbed by the trapping water and given off from its upper surface. Ammonia has been found to become perceptible through an unbroken trap in fifteen minutes. Moreover, when the water remains stagnant, bubbles of putrefactive gases may be formed, and, by their bursting, particulate matter may be discharged. Occasional changing of the trapping water is necessary, and the drain must be ventilated to prevent its air contents from becoming too foul, or subjected to so much pressure that the water-seal is forced. A trap to fulfil all these requirements must be self-cleansing and must maintain an effectual seal between the drain and the outer air. For the former purpose it must be free from all angles and corners that can retain filth, and for the latter it must have a water-seal not less than $1\frac{1}{2}$ inch deep.

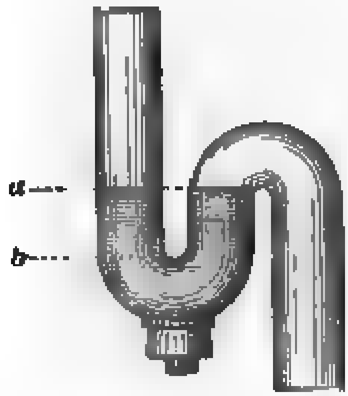

Fig. 10.—Siphon Trap (S-trap) with access screw-plug for cleansing.
a, *b*, the seal.

The seal is liable to be broken by a number of circumstances. First, pressure within the drain may force its air contents through the trap. This can be prevented by ventilation of the drain. Secondly, if the momentum of the water discharge be great, the *water in* the trap may be driven out. This can be *obviated by shaping* the trap so that the water-holding *portion is contracted*, and the descending arm is larger

and square at the outlet. Thirdly, if the descending arm is long and runs full it may empty the trap by siphon action. This can be avoided by ventilating the top of the trap beyond the seal. Fourthly, the same result will sometimes follow when two or more pipes are connected together, the discharge from one sucking out the water from the trap of the other. This can be prevented in like manner. Lastly, the seal may disappear by evaporation, if the trap is little used.

Drainage of the subsoil of a house is not necessary in all cases, but when the site is damp some provision of the kind should be made. The drain laid for this purpose should consist of suitable earthenware pipes with the joints left open, and laid to a proper outfall, preferably in the open air, but if into a drain connected with the sewer, the connection should never be direct. The subsoil drain should always discharge into a trap, and should be ventilated at or near the trap by a shaft or upright pipe carried above the surface.

The drain must be laid with a sufficient fall for the purpose of enabling it to clear itself of its solid and fluid contents, and it is generally accepted that this should be one in forty, giving a velocity of flow in a 4-inch drain of about 3 feet per second.* Further, in discharging into a sewer, the drain should be connected with the lower half diameter of the sewer.

The drain should be constructed of glazed stoneware pipes with cemented watertight joints, or preferably, if the drain be beneath a building, of iron pipes (of which the interior has been coated with Angus Smith's solution) jointed with lead. In all circumstances the drain should be laid on a bed of concrete, and if it be made of any other material than iron the whole drain should be embedded in concrete. It is customary to use drains having a diameter of 6 inches, but a four-inch diameter is

* Maguire's "decimal" rule is convenient but not invariably practicable; *1 in 40 is a proper fall for a 4-inch pipe, 1 in 60 for a 6-inch pipe, 1 in 90 for a 9-inch pipe.*

frequently sufficient for houses of moderate size. It should never be less than this.

As a general rule, the drain should not be laid beneath a building, but in the case of terrace houses it is often impossible to adopt any other plan. In this situation the drain must be laid in a direct line beneath the building and be embedded and covered in concrete not less than 6 inches thick; the top of the drain at its highest point must not be less than a distance equal to the full diameter of the drain below the surface of the ground under the building. Means of access should be provided outside the house.

An important point in connection with drain construction is the prevention of air from the sewer passing into the drain, or from the drain into the house. The former of these risks is guarded against by the insertion of a trap in the drain (*interceptor*) as near as possible to the point of its connection with the sewer. Such an interceptor is usually provided with a "raking arm" into the drain. The drain should be ventilated immediately on the house side of the trap, by a shaft carried up above the ground level; this will serve a double purpose, by admitting fresh air into the drain, and also affording a free outlet in case the trap is forced by pressure of sewer air. The opinion appears to be gaining ground that if drains are properly laid in concrete, and the ventilating pipe is carried up above the roof, interceptors are not necessary; that if the ventilating pipe of every house drain (whether soil pipe or not) acted as a ventilator to the sewer, the amount of foul air escaping would be so thoroughly and widely distributed as to create no nuisance; and that the interceptor may cause stoppage of the drain, especially if the gradient be slight. It should be added that, as a rule, bye-laws require an interceptor, with access thereto. A more complete and necessarily a more costly

arrangement is that of an *inspection chamber* at this point (Fig. 11); the drain is continued through this chamber in earthenware channels, and the arm in the trap, which is intended to allow the drain to be cleared between the trap and the sewer, is extended into the chamber. Branch drains are connected with the main channel by branch channels in the floor of the inspection chamber

In connecting drains with one another, no right

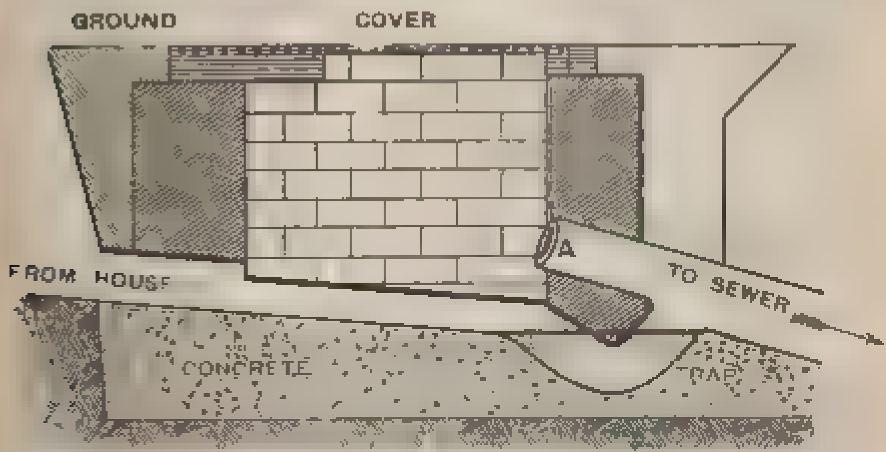

Fig 11 —Disconnection (Inspection) Chamber.
A, "raking arm," closed by a cap

angle joints must be formed, either vertical or horizontal They must be made to join obliquely in the direction of the flow.

The second risk, that of air from the drain entering the house, is guarded against (1) by ventilation of the drain; (2) by trapping all inlets to the drain, except those required for its ventilation, (3) by trapping *and disconnecting* all *indoor* drain inlets; (4) by proper jointings and efficient plumbing.

The proper ventilation of the drain is secured by continuing the soil pipe in its full diameter above the level of the roof. By this means air entering by the *opening near the trap* in the main drain can pass along

the whole drain, and issue from the soil-pipe. The openings referred to must be covered with suitable gratings to keep out leaves and dirt, and to prevent birds from building nests in them, the open spaces in each grating being at least equal to the section of the pipe thus covered. The sectional area of the ventilating pipe should not be less than that of the drain which it ventilates.

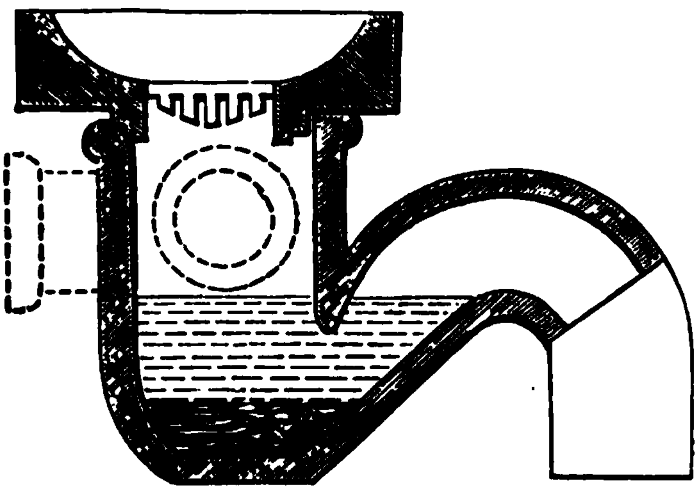

Fig. 10.—Yard Gully.

Soil pipes should be situated on the outer walls of the house, and their junction with the drain, often a weak point in construction, will then be outside the house. If through any accident the junction of the soil pipe with the drain should be opened, the escape of gas will be into the open air.

Whether the soil pipe is used for the purposes of ventilation or not, bends in its course should be avoided as far as possible. As a general rule, the diameter should be 4 inches. Iron and lead are both used; lead is more expensive but more durable, and free from joints that may become loose. Rolled (*i.e.* seamless) lead is necessary if the soil pipe is inside the house.

The old practice of trapping the foot of the soil pipe is inadmissible, since it prevents ventilation and impedes the escape of sewage.

Waste-pipes.—The overflow of a cistern should simply be carried through an external wall to discharge in the open, so that no drain gases can enter the cistern, and waste of water from faulty apparatus is at once seen. But the foul-water wastes of sinks,

lavatories, and baths must be differently dealt with. Slop-sinks used for disposal of urine must be treated as water-closets, but all other wastes should be made to discharge over trapped gullies in the open air. Such *disconnection* renders it impossible for the air from the drain to enter the house.

Fig. 13.— "Anti-D" Trap.

A suitable form of gully-trap is shown in Fig. 12. Here the waste pipe discharges through a side opening beneath the grating, and above the water in the trap. The grating must be large, with a free opening kept constantly clear, or else the primary object of disconnection is lost. More commonly the waste-pipe pours *over* the grating, with more effective disconnection but some risk of splashing. Neither of these methods complies with the requirements of the Model Bye-laws that the waste-pipe shall discharge over a channel leading to a trapped gully grating at least 18 inches away.

Waste-pipes should always be trapped, and the trap situated as near as possible to the sink or bath. The interior of the pipe becomes coated with decomposing soap or fat, which is itself offensive; the higher temperature of the interior of the house leads to an offensive in-draught through an untrapped pipe, still more marked after the pipe has been heated by discharge of hot water.

A convenient form of trap is one shaped like an **S** (Fig. 10), and fitted with a screw at its lowest point, by the removal of which it is possible to cleanse the trap. Where the momentum of the water discharge is great, a useful modification of the trap is that shown in Fig 13, by which the unsealing of the trap is prevented.

Fig. 14. Bell Trap.

From the trap the waste should be carried as rapidly as possible through the wall, and then descend to the gully. When the waste-pipe is long, or when two or *more waste-pipes* are connected, ventilation of the

trap is needed to prevent siphonage, and is effected by an air-pipe passing from the top of the trap, beyond the seal, to the open air. The common "bell trap" shown in Fig. 14 is open to more than one objection; the depth of the seal is inadequate (about $\frac{3}{8}$ inch); it readily becomes choked with grease, being far from self-cleansing, and as a result the grating is often removed to let the water pass away, and on each such occasion the waste-pipe is untrapped.

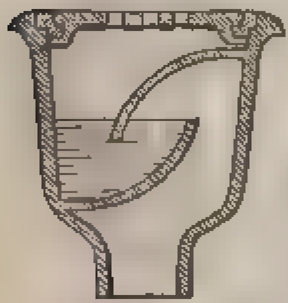

Fig. 15.—Antill's Trap.

The D trap shown in Fig. 22 is the worst of all, as it readily becomes filthy, and always leads to the retention of a large amount of offensive matter.

In large households the gully into which the scullery sink waste discharges is liable to become choked by sand and grease (solidifying on cooling). In such cases frequent cleansing is essential. A "grease-trap" (*i.e.* a gully, so constructed that the outflow of liquid is not prevented by solid accumulation at the surface or bottom), such as is shown in Fig. 16, is sometimes adopted.

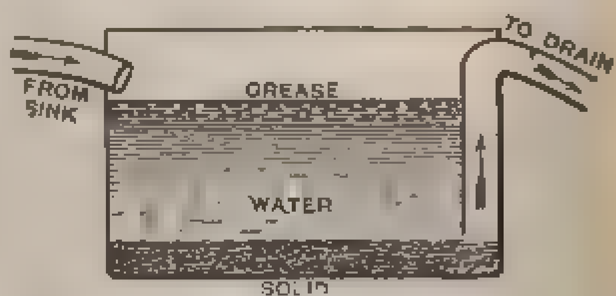

Fig. 16.—Grease Trap.

Wastes from sinks and baths in upper storeys are sometimes discharged into the head of a large pipe, which may or may not also receive rain-water. This receives disconnection, but is liable to cause nuisance, by fouling of the large pipe with soapsuds and grease.

A better arrangement is to carry the waste directly to the gully, due precautions being taken against siphonage. A waste-pipe of 1½ inch diameter is sufficient even for baths, and if two or more be joined, they may discharge into a somewhat larger pipe; a ventilating pipe being carried from the upper end of the common pipe to some convenient position above the level of the windows.

The rain-water pipe should not be used as a soil pipe, or as a ventilating pipe to the drain. Thorough ventilation of the drain is most needed at times of heavy rain, when the rain-water pipe is least able to act in this way; and as the rain-pipe cannot be carried above the eaves of the roof, it often discharges its air contents too near to a window. For the latter reason this pipe should not be connected with the drainage system, but should be made to discharge over a trapped gully or a channel leading thereto. It is well that a waste pipe in frequent use should discharge into the same trap, thus avoiding risk of unsealing by evaporation in dry weather.

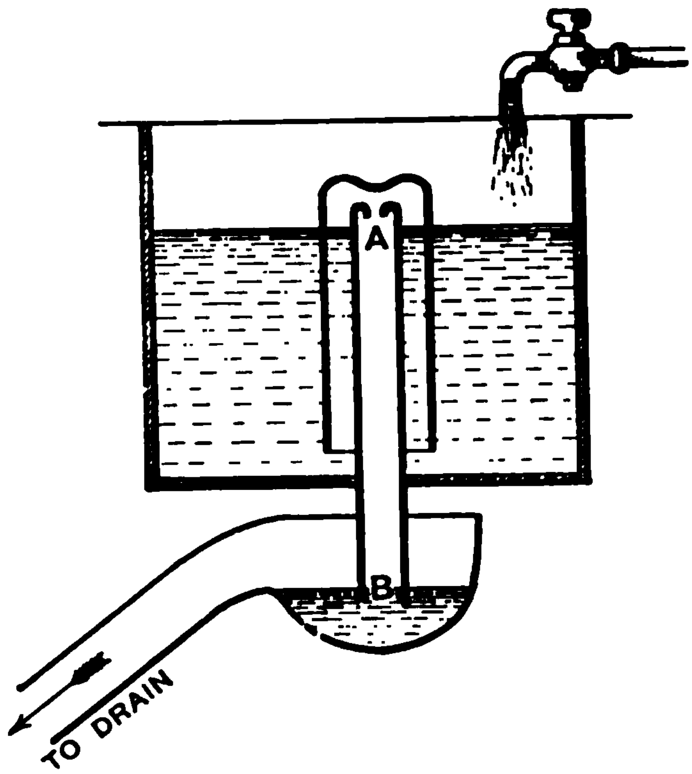

Fig. 17.—Flush-tank.

In small houses the ordinary discharge of liquid is usually sufficient to scour the drain and make it self cleansing, but where necessary this can be supplemented by a *flush-tank, periodically discharging its contents into the drain (Fig. 17).* This is a cistern containing a

large outer tube closed at the upper end and inverted over a small inner tube A B, thus forming a siphon. A B is open at the top, and passes vertically down through the tank, to dip slightly under the surface of water in a chamber below the tank, the water in this lower part being kept at the required level by means of a weir, practically forming a D-trap. As the water rises in the tank from the discharge into it of a tap or a drain, some of it eventually runs over the top of the tube A B; carrying with it air which is forced through the water at B, and cannot return; siphon action is started, and the whole contents of the tank are emptied into the drain.

Testing of drains and soil pipes can be most effectually done by means of (a) the water test. For the purpose of testing the horizontal drain, a plug is inserted at that portion of the drain which is near the intercepting trap intervening between the drain and the sewer; the drain is then charged with water, care being taken to see that there is no leakage through or at the side of the plug, and the water is allowed to fill the drain to the top of one of the surface traps connected with it. At the end of from half an hour to an hour the maintenance or subsidence of the water level in this trap will show whether there is any leakage. In testing a large system of drainage it is necessary to take each section separately. In testing soil pipes with water, the plug must be inserted at the bottom, and if several water-closets are connected with the same soil pipe the trap of each must be plugged.

(b) Smoke pumped into the drains previously plugged in the same way serves also as a useful test. The process must be continued until the smoke is seen issuing from the soil pipe or ventilating pipe, and if several of these are connected with the same drainage system it is necessary that each must be plugged at the top as smoke issues from it until the whole system is charged, care being taken to prevent the smoke from being forced through the traps; smoke in these circumstances, when there is leakage, soon finds its way into the interior of the house.

(c) Peppermint was formerly used in the same way; two or more ounces of the oil was either poured down a soil pipe with

a pailful of boiling water, or down some trap situated outside the house connected with the soil drain, the scent of the oil of peppermint found its way into the house in the event of defective pipes. Chemical "testers" such as Kemp's or Kingzett's are now commonly used. These are composed of some strongly

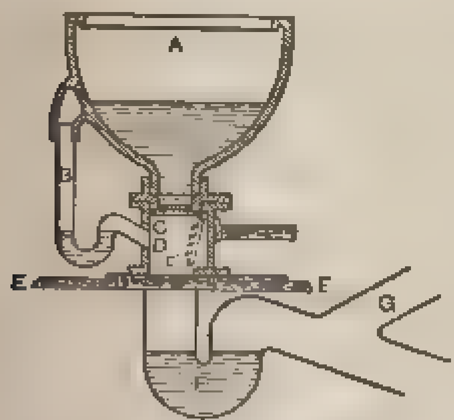

Fig. 18.—Valve Closet.

A, basin, flushing-rim above; B, trapped overflow; C C, valve, closed and open; D, valve-box; E E, safe; F, trap, ventilated at G.

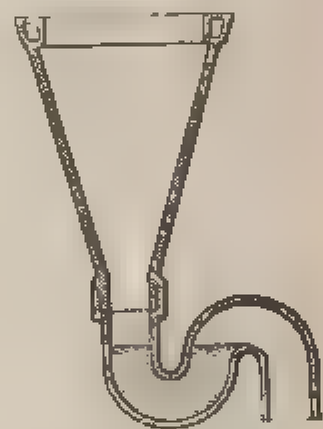

Fig. 19.—Long Hopper Closet.

Fig. 20.—Wash-out Closet.

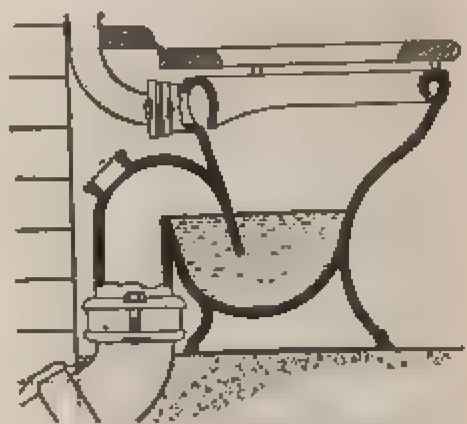

Fig. 21.—Wash-down or Short Hopper Closet.

smelling chemical, *e.g.* calcium phosphide, which, when moist, evolves phosphoretted hydrogen, and when the tester is washed into the drain over the trap, the water soaks the paper fastener, and the spring being liberated the contents escape. If the drain be defective the odour escapes into the house in about fifteen minutes.

¶ The surfaces of the **water-closet** must be non-absorbent, and in its shape and capacity the basin must be able to receive the water that is discharged into it, and to allow all matter it receives to fall directly into water without soiling the sides. In both the *valve closet* (Fig. 18) and the *wash-out* pattern (Fig. 20), water is held in the basin independently of that in the trap below. In the one case it is held by a movable valve, in the other by a fixed dam, over which the contents are carried by the flush. This last form is not wholly satisfactory. In the *plug closet* the valve or dam is replaced by a solid plug, which works vertically in a side-chamber similar to that shown in Fig. 18. *Hopper closets* are of two kinds; the basin of the old *long hopper* (Fig. 19) is from its shape and construction liable to become filthy, and it has usually a bad flush; the *short hopper* or *washdown* (Fig. 21) is free from objection, and possesses the advantage of a large water surface owing to the form of the trap being such as to allow the water to stand high in the basin. Added to this there is a deep water seal, and the cleansing of the trap is greatly facilitated. There is at present a wholesome tendency to dispense with all unnecessary woodwork and fittings, and to reduce the closet to its simplest form.

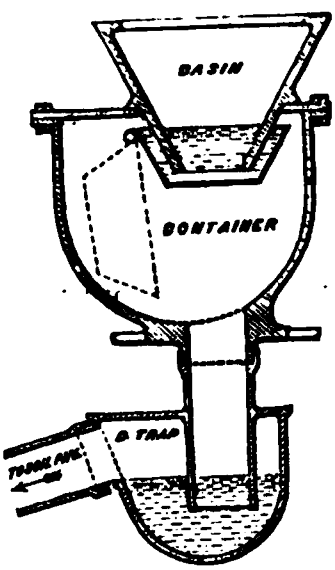

Fig. 22.—Pan Closet, with D-trap.

The old *container closet*, or *pan-closet* (Fig. 22), is especially objectionable, and is prohibited by the Model Bye-laws. The basin discharges into a large receptacle, which becomes foul and, every time the valve is opened, allows polluted air to escape.

The apparatus, of whatever kind, should be provided with a flushing rim which directs the water

over the whole surface, and maintains it in a state of cleanliness. It is essential that the flush should be of sufficient volume (not less than two gallons), delivered with sufficient force (and for this purpose the pipe must not be less than $1\frac{1}{4}$ inch in diameter), and properly directed so as to wash the basin effectually. The flush must on no account be taken from a service pipe or a cistern that supplies water for household purposes, but from a special cistern. Gases and even filth have been found to make their way from the closet basin up the (usually empty) delivery-pipe.

It is unnecessary to discuss at any length the traps used in connection with water-closets. The **S**-trap is here again found to be a useful form, but liable occasionally to become unsealed when the momentum of the water-discharge is great; for this reason, therefore, the form of trap (Fig. 13) recommended in connection with waste pipes to obviate this difficulty is preferable. The **D**-trap is altogether inadmissible.

Water-closet traps are liable to become unsealed in the same manner as those of waste pipes (page 230). Wherever two or more discharge into the same soil pipe, ventilation of the traps is necessary, the ventilating pipe from the trap of the lowest water-closet may receive the ventilating pipe of each above, and be finally connected with the soil pipe above the highest water-closet, but while this arrangement is permissible it is frequently preferable to carry the antisiphonage or ventilating pipe independently above the roof.

A closet or bath on an upper floor is usually provided with a *safe* to receive any overflow or splashings. The waste-pipe from the safe may be treated in the same way as an overflow from a cistern, *i.e.* simply carried through an external wall,

and made to discharge a few inches from the brick-work.

Trough closets are sometimes adopted in schools or factories. A long trough filled with water passes beneath the seats of a number of closets placed side by side. At stated intervals the trough is flushed, automatically or by an attendant, and the contents are carried away to the sewer through a trap at the outlet end. The automatic flush may be effected by a tilting receiver placed at the upper end of the trough, and so arranged as to capsize and discharge its contents as soon as it becomes filled by a regulated stream of water ; or still better by a flush tank fed by a stream of water and discharging itself into the trough by siphon action as soon as it becomes full. In either case the frequency of the flush can be regulated by the supply of water.

In *waste-water closets* the flush is effected by the household waste-water, the object being of course to avoid the expense of a separate water supply. The drainage from a row of houses is conducted to a flush tank placed at the end of the row farthest from the sewer. From the tank a large pipe drain passes to the sewer, and separate closets are placed upon its course, the excreta simply falling through large vertical drain pipes into the drain below, and remaining there until the next flush sweeps them away into the sewer. The drain has a siphon trap after passing the lowest closet, and a manhole or access chamber at the same point for use in the event of obstruction.

In like manner the waste-water of single houses has been utilised for flushing single out-door closets. For closets of this type, which are known as *slop closets,* the household waste-water, supplemented if necessary by the rainfall, is collected in a " revolver," or " tumbler," an earthenware vessel working on

pivots, and so constructed as to overbalance when full, discharging its contents forcibly along the drain, and then swinging back to its former position. On the drain, beyond the tumbler, is a large siphon trap, and the closet consists of a wide vertical shaft over this, so that the excreta fall into the water of the trap, and are carried away by the next flush.

The use of waste-water for flushing is attended with practical difficulties from the over-concentration of sewage, and the liability of automatic appliances to get out of order

Intermediate between the water-carriage and dry systems come certain Continental and other methods which may be described briefly. The *fosse permanente* is a large water-tight underground pit, to which pipes from the closets conduct the excreta, the pit is emptied at long intervals by suction through hose into an air-tight cart. The *fosse mobile* is a closed movable tub placed outside the house, and connected with a fixed pipe that communicates with all the closets, etc., in the house, the tub is simply removed and replaced by another when full. In *Liernur's system* a number of closets are connected by means of iron pipes with an air-tight tank, which is at intervals exhausted of air, so that the excreta are drawn into it.

Dry systems of excreta removal, otherwise known as "conservancy systems," include *privies*, *pail-closets* (with or without ashes), *ash-closets*, and *dry earth-closets*. In some localities privies are called earth closets, but this use of the term is misleading.

The *privy and ashpit*, or midden system, which is still employed in certain towns, and in most rural districts, aims at the deodorisation and drying of the excreta by admixture with ashes. The best construction is that of a small watertight pit, not drained but roofed over to exclude rain, and so arranged that the excreta and ashes become thoroughly mixed. For this purpose either the ashes must be thrown in through the closet seat, which may be hinged so as to be lifted *en masse*, or else a "shoot"

or sloping slab must conduct one or the other to a common point. The floor should be smooth, and raised a few inches above the level of the adjoining ground. Very few middens fulfil these conditions, however.

The contents ought to be removed at fixed short intervals by the **S.A.**, and the work should be done at night or early in the morning so as to minimise the nuisance. Unfortunately it is still common to leave the emptying of ashpits to contractors, or even to the owners and occupiers, and the interval is frequently several months instead of a week, as prescribed by the Model Byelaws.

Privies alone, without admixture of ashes or other deodorants, are also met with. The receptacle should be small, and its contents frequently removed, but at best the system is more offensive than when ashes or earth are added.

Pail- or *tub-closets* are simply miniature privies, in which the pit is represented by a movable pail placed beneath the closet seat. The full pails are removed and replaced by clean empty ones at regular intervals not exceeding a week. Close-fitting covers should be used during removal of the full pails. There are several modifications of this system. On the "Rochdale system" the pails contain excreta alone, while in some towns the ashes and other dry household refuse are added; or the ashes are thrown upon a sifter, and only the fine ash falls into the pails; or the Goux system is used, the cleansed pails being lined with a dry, absorbent packing of compressed peat or like substance.

In Morell's cinder-sifting *ash-closet* the ashes are thrown in by a separate opening, and by a simple automatic arrangement are sifted, so that only the fine ash falls upon the excreta, the cinders finding their way to a separate chamber for further use as fuel. The receptacle is permanent and in this respect

resembles a privy rather than a pail-closet, but it is small and so arranged as to be readily emptied by a special opening. Taylor's closet is somewhat similar in principle, but the urine is collected separately.

Dry earth closets have a small receptacle, fixed or movable, beneath the closet seat. Clean, dry earth (about $1\frac{1}{2}$ lb.) is thrown upon the excreta, either by hand or by automatic delivery from a hopper, every time the closet is used. A constant supply of fine dry earth is needed, ordinary mould being the best, owing to its richness in nitrifying organisms. Sand is less efficacious.

Destination. Water-carried excreta pass into the ordinary sewers, and their ultimate disposal will be considered in another section.

Pails are emptied and cleansed at a central depôt, and are then ready for further use. Their contents are sent into rural districts as manure, either in the crude state or after conversion into "poudrette" by drying and other treatment. For the manufacture of poudrette the excreta (free from ashes) are heated in revolving cylinders, so as to drive off the moisture. Sulphuric acid is often added to fix the ammonia.

Contents of ashpits are commonly sent away at once into the country. The refuse of ash-closets or pail closets is also available as manure.

The earth from earth-closets can be dried and used again and again, and finally restored to the garden or field. The organic matter disappears by nitrification.

Comparative advantages of water-carriage and dry systems:—

1. *Hygienic.*—Water-carriage is by general consent the most satisfactory in houses of the better class, where cleanliness and freedom from effluvia are the main considerations, and due care in use can be relied upon. The excreta are at once carried right away from the premises. Water-closets may

safely be constructed practically within the house, a matter of great convenience. The objection that the sewers receive the specific poison of enteric and other fevers may be met by the use of disinfectants, and has not yet been proved to be weighty. It has been urged that indoor water-closets afford facilities for the entrance of sewer air, especially in the case of obstruction of the sewers by floods or other causes. Indeed, it has been observed in more than one enteric outbreak that the inmates of large water-closet houses upon high ground suffered more than the poorer inhabitants of lower districts with outdoor closets. This danger, however, can scarcely occur unless there is grave defect in construction or management, and it extends equally to indoor sinks. As applied to poorer dwellings water-closets often fail. Owing to carelessness or misuse, the mechanism becomes deranged, or flushing is neglected, and the drains become choked by bulky objects improperly introduced into them. Automatic flush closets, trough closets, and even slop-closets, if kept under supervision, are to a great extent free from this objection, since they are not liable to become deranged by carelessness on the part of those using them. Water closets of ordinary construction are made serviceable, even in houses of the poorest class, by careful supervision on the part of the **S A.** Neglect of hand flushing may be met by automatic mechanism connected with the door or the seat. The water-supply of outdoor closets is liable to be stopped by frost, but this rarely happens if the cistern and pipes are properly cased.

Privies and ashpits are being abandoned in most towns, although still almost inevitable in country districts where there is neither efficient drainage nor organised scavenging. The retention of large quantities of excreta and other organic matter near dwellings is in itself objectionable, and the nuisance becomes great at the time of clearing out. It is probable that such an arrangement favours the spread of diseases that have relation to filth, and especially those in which the poison is contained in the excreta. The case becomes worse when, as almost invariably happens, the pit leaks and allows its contents to pollute the soil and the subsoil water.

Pail-closets have the advantage of extreme simplicity, and cannot be deranged by carelessness or anything short of wilful destruction. Although not removed instantly, as in water-closets, the excreta remain near the dwelling for a few days only, instead of putrefying for weeks or months as in middens. The weekly or semi-weekly visits of the scavengers ensure a certain degree of cleanliness, apart from the mere substitution

of cleansed pails. It is claimed that in the event of such diseases as enteric fever occurring, the pails and their contents can be disinfected; unfortunately not all the infective matter is thrown into the closet, and at best its disinfection in any true sense would be difficult; but it is quite possible to adopt the simple precaution of supplying specially marked pails to infected households, and cremating the contents of such pails when collected. Pail-closets that receive excreta only are inevitably offensive, however frequently changed. The addition of ashes lessens the effluvia, and the average amount of ash produced by an artisan household is found to be sufficient for the purpose.

Dry-earth closets are convenient and free from effluvia. The difficulty of ensuring a constant supply of suitable dry earth, and of removing the products, has hitherto prevented their adoption in towns. In rural districts, where these difficulties do not exist, they offer great advantages, but can only succeed when used with care and kept under supervision.

2. *Economic.*—Water-carriage involves some cost, either to the individual or to the public, in the extra consumption of water, although this objection does not apply to those systems in which the flushing is effected by the household waste water. Drains and sewers have to be provided in any case, so their cost cannot be charged to the account of water-carriage systems. The increased volume of sewage in water-closet towns or districts is far less material than is generally assumed, and forms at most only a small fraction of the enormous volume derived from rainfall, soil drainage, household waste water, trade effluents, and other sources. It has been found that the addition of water-closet sewage scarcely alters the chemical composition of the average sewage of a town. Hence the necessity of treating the sewage by irrigation or other means is quite independent of the admission of water-borne excreta to the sewers.

Water-carriage obviates some part of the expense of the scavenging required by the pail-closet system, but there must still be a costly organisation for collecting the dry household refuse, which, without the addition of excreta, is an unsaleable commodity, and further expense is therefore incurred in disposing of it after collection.

A similar objection is often urged from the theoretical side, namely, that the enormous dilution of excreta by water renders it difficult or impossible to recover them again for manurial purposes, and hence the soil is steadily impoverished by depriving it of what should naturally be returned to it in exchange for the crops that it yields. Vivian Poore's dictum

was that the proper destiny of organic refuse is immediate burial just below the surface of the soil, and on this principle he objected to water-carriage. This argument has some weight as bearing upon the still common practice of pouring the sewage of towns into rivers or into the sea.

From the purely financial point of view the objectionable midden system probably costs less than any other.

The pail system involves a heavy initial outlay in buildings and plant, and an expensive staff to manage it efficiently. On the other hand, some part of the expense is recouped by the sale of manure, and a scavenging staff must in any circumstances be maintained for the removal of dry refuse. The market value of the excreta is greater if unmixed with ashes, but it is questionable if the gain is sufficient to compensate for the cost of a separate collection of dry refuse, which, as already explained, is undesirable. The dry systems ensure the return of most of the solid excreta to the soil, but a great part of the liquid excreta, which are more important as fertilisers, goes with the household drainage in any case.

Reviewing the whole question, the privy system must be regarded as contrary to sound principles of hygiene wherever facilities exist for any other arrangement. Water-closets are most suitable in town, and water-closets or earth-closets in the country.

Removal of ashes. Where water-closets, or pail-closets for excreta alone, are in use, the ashes and kitchen refuse have to be removed separately. Small covered tubs or boxes (preferably of metal) should be placed in a yard or outhouse, and emptied at short and regular intervals by the scavengers. Frequently, however, large "bins" or fixed "ashpits" are employed, the contents of which are allowed to accumulate for long periods.

Household refuse ought to consist of little more than ashes, the animal and vegetable refuse from the kitchen being easily burnt.

Trade refuse, from slaughter houses, markets, fish and fruit shops, and many other sources, requires prompt removal. This duty is often left to the *proprietors,* who make private arrangements with *farmers, etc.,* to remove the refuse for use as manure,

or convey it at their own cost to some suitable place. It is difficult to ensure proper system and regularity unless the **S.A.** itself undertakes the task, and the same difficulty may occur in urban districts in regard to manure from stables and cowsheds. Under the Public Health (London) Act, 1891, s. 36[2], the local authority may by formal resolution prescribe frequent removal.

Road sweepings and the contents of street gulleys have also to be dealt with.

Destructors.—Any kind of refuse which contains organic matter, but which cannot be at once disposed of as manure, should be burnt. The refuse is thrown in at the top of a furnace, and becomes dry as it sinks down; all organic matter is burnt off, and at intervals the mineral matter, or "clinker" (forming about 30 per cent. of the refuse burnt), is raked out below, to be used for road making, filling up hollows, etc. In the best modern destructors the clinker is withdrawn in large slabs and freely slaked with water to prevent flaming when tipped. Silica and ferric oxide are the chief constituents of clinker, which is now much used for bacteria beds, mortar-making, etc. After the furnace is started, the organic matter in the refuse is usually sufficient to maintain the fire without the addition of other fuel.

Numerous forms of destructor are now in use. They consist of furnaces of a varying number of cells and are charged in different ways ("shovel fed," "top fed," mechanical charging, etc.). The furnaces are not unfrequently multitubular, or fitted with Babcock and Wilcox boilers, and the necessary draught is obtained naturally or by means of fans or steam blowers. They may be divided into two chief groups, the "single cell system" (*e.g.* Horsfall's, Fryer's, Warner's, Baker's) and the double cell or *continuous grate system* (*e.g.* Meldrum's, Heenan's,

Sterling's); there are, of course, various modifications. By the single-cell system is meant a destructor with a boiler between every two cells, so that there is no intermingling of the gases from two or more cells. It is desirable to have complete combustion in the cell itself, but if necessary the fumes can be passed through a second furnace.

Sewers may be required to convey :—

(i.) *Household effluents,* including waste water from baths, lavatories, sinks, and all liquid refuse and urine. Where there are water-closets, the volume of sewage is somewhat increased, but its composition is little altered. Latrines, etc., attached to works, schools, or public resorts may be included under this head.

(ii.) *Trade effluents* of all degrees of impurity, from the comparatively pure water from condensers to the foul effluents from dyeworks.

(iii.) *Water used for public purposes, e.g.* watering streets, fountains, public urinals, baths, etc.

(iv.) *Rainfall,* of which the first portions (especially road-washings) are extremely impure.

(v.) *Subsoil water,* and even small natural streams.

Modern sewers, like house drains, are impervious tubes, oval or round in section. Their size varies according to requirements, say, from 9 inches to 12 feet in diameter. If the diameter is not greater than 1½ or 2 feet, glazed earthenware pipes set in cement are usually employed, laid in the manner described in speaking of house drains. Sewers of larger diameter than 18 inches are generally constructed of brick set in cement upon a bed of concrete, and are oval or ovate in section, so as to secure a better scour and less friction when little sewage is passing than if the section were circular. Sewers should be laid as far as possible in straight lines, with means of inspection and access at every change of direction. All junctions

should be obliquely in the direction of flow, and the tributary sewer or drain should have a fall into the sewer at least equal to the difference in their respective diameters. It is desirable that the rate of flow should be not less than 2 feet per second, and 3 feet is better. Hence the minimum gradient should range from 1 in 250 to 1 in 750, according to the size of the sewer. The gradient should preferably be uniform, except at angles and junctions, where it is desirable to allow extra fall.

Manholes should be provided at short distances, and at all important angles, junctions, and changes of gradient, to allow of access for inspection and flushing. Flush-tanks may with advantage be placed at the head of each sewer. Flushing is chiefly required in sewers with insufficient gradients, at "dead ends," and in hot dry seasons, when the flow is smallest and decomposition most rapid. It may be effected more or less automatically by means of flush-tanks, or by temporarily damming back the stream and then allowing it to escape with a rush, or by suddenly discharging a large volume of water into the sewer through a manhole. Little benefit is likely to result from the perfunctory "flushing" of sewers that is commonly practised, consisting as it does of simply pouring a small and inadequate volume of water into the sewer through a hose, at intervals of several weeks. There is little to be gained by the addition of "disinfectants" to the water used for flushing.

The air of sewers ("sewer gas") has no constant composition, and if the sewer be properly constructed, well ventilated, and sufficiently flushed, may differ but little from outside air. Much depends upon the sewage being removed quickly, or, on the other hand, being allowed to stagnate and undergo decomposition. In the latter case the air of the sewer

becomes foul; oxygen is lessened, carbonic acid increased, and there is much organic matter, together with variable quantities of marsh gas, sulphuretted hydrogen, and ammonium sulphide. The exact composition of the organic matter varies, but its properties are similar to those of the organic matter in respired air. Micro-organisms adhere to moist surfaces, and hence the air of well-constructed sewers is, on the whole, remarkably free from them, except near fresh air inlets and at junctions, where splashing occurs. Neither bacteria nor other solid particulate matters are, under ordinary circumstances, given off from quiescent liquid surfaces; but if putrefaction be allowed to occur the bursting of bubbles may recharge the air with them. Haldane found in the air of a well-constructed but unventilated sewer in Bristol 20 volumes of carbonic acid per 10,000, but only two micro-organisms per litre, half of which were moulds; and Lawes and Andrewes demonstrated that the air of well-constructed London sewers contained fewer bacteria than the air of the street above, and the species found were not of sewage origin. It thus becomes clear that sewer gas can rarely, if ever, convey pathogenic organisms.

Air contaminated by sewage emanations may, however, be a cause of diarrhœa and other gastro-intestinal disturbances, and of certain forms of sore throat. Anæmia, depression, and general ill-health may result from protracted exposure to such an atmosphere. Cholera, enteric fever, pneumonia, erysipelas, puerperal fever, and diphtheria have a much heavier incidence, both in numbers and severity, upon persons exposed to these conditions. It is not necessary to assume an origin *de novo* in such cases, or even in the case of diarrhœa and sore throat, the evidence being consistent with the supposition either that the specific poison is sometimes carried by such

emanations, or that their effect is merely to predispose to the disease. There is no evidence of any specific relation between sewer gas and small-pox, measles, or whooping-cough.

Men working in well-ventilated sewers are not found to suffer any ill effects, but if ventilation is wanting they are liable to ophthalmia and to syncopal or apoplectic attacks. It is said that venereal disease is greatly aggravated by this employment. Meat, milk, and other food substances readily decompose if exposed to sewage emanation.

Ventilation of sewers. Foul gases are given off by sewers, more especially if, from insufficient gradient or obstructed outfall, they become stagnant or "sewers of deposit." Hence it becomes necessary to provide means of vent or ventilation in order to avoid the risk of the pent-up gases forcing their way into houses through traps.* For this purpose openings are provided at intervals which should not exceed 100 yards. Some of these openings act as inlets, others as outlets, and the latter only are, of course, liable to be offensive. The conditions that determine the direction of the currents of air are complex, including force and direction of wind, internal and external temperature, volume and velocity of sewage, etc., so that the result cannot be predicted, and is not even constant in the same sewer. Speaking generally, the tendency is for the air current to pass in the reverse direction to the sewage, that is, from a lower to a higher level, so that the highest openings are most liable to be outlets, and the lowest to be inlets. Nevertheless, every opening may at different times act both parts.

The plan usually adopted is to provide grated openings in the roadway, leading directly to the sewer beneath, a cage being suspended immediately beneath

* *In Bristol the sewers are not ventilated. The house drains are, however, provided with interceptors*, and all street gullies are trapped.

the opening, to catch any solid débris that may fall through. It was formerly customary to place trays of charcoal in the openings in order to deodorise the sewer gases, but the charcoal obstructed the opening and soon became inert. To obviate annoyance from effluvia at outlets, ventilating shafts (in substitution for these openings) are often attached to houses or even to trees; these shafts should be, but rarely are, of sufficient calibre efficiently to ventilate the sewer. Sometimes factory chimneys are utilised for this purpose by carrying the vent into the stokehole or chimney. Another device (Keeling's) is to ventilate the sewers through hollow lamp posts with gas jets inside serving to create a strong upward current and (it is claimed) to destroy all effluvia.

If carried out on a large scale these special arrangements are costly. It is contended by the advocates of simple openings at the street level that the true remedy for offensive outlets lies in proper construction and flushing of sewers, and increasing the number of openings—that is, in approximating to the condition of an open sewer. Some authorities rely upon ventilating the sewer by means of the vents of each house drain connected (see p. 232).

Rain and subsoil water.—If the sewers are watertight, as they should be, the subsoil water cannot gain access to them, and separate provision must be made for draining the soil, although a certain quantity of water flows away along the comparatively easy track outside the sewer. Sometimes provision is made for this by leaving a space beneath the sewer for the ground-water to pass along.

It is becoming customary to exclude also the rainfall from the sewers, and thus avoid dilution of the sewage and sudden changes in volume, which add to the difficulty of treating it by precipitation or filtration. The first washings of the streets are very

foul, and should be admitted to the sewers. When the "separate" system is adopted, the rain water is taken away by another system of drains, which may with advantage be permeable, and so available for draining the subsoil.

Capacity of sewers.—In towns only a comparatively small surface of ground is pervious, and almost all the rainfall rapidly makes its way to the sewers. Hence in planning the size and gradients of sewers it is necessary to provide for the immediate removal of the maximum hourly rainfall, say, 1 inch per hour *plus* the maximum volume of sewage from other sources.

Parkes gives the following formula for calculating the discharge from a sewer:—

$$V = 55\,A \times \sqrt{2DF}.$$

V being the velocity, in cubic feet discharged per minute,
A, the section area of the current,
F, the fall, in feet per mile,
D, the *hydraulic mean depth*, in feet. This is ¼ of the diameter of the pipe, if running full or half-full; in all cases it is equal to the section area of the current divided by the "wetted perimeter"—that is, by the length of the arc formed by that part of the section of the circumference which is in contact with the stream.

When a sufficient fall cannot be obtained, *Shone's pneumatic system* offers great advantages. The sewage is conducted to one or many central collecting tanks by gravitation through drains and sewers of ordinary construction, and is forced through pipes, leading from the tanks to the outfall, by means of compressed air. Thus difficulties arising from inequalities or from low level of districts to be drained can be overcome.

The **composition of sewage** varies from day to day, and from hour to hour, since both the filth and the diluting water are inconstant in amount. There are variations according to season and weather, and trade effluents may be important factors. The admission or exclusion of rain water makes a very great difference, but the presence or absence of water carriage of excreta does not seem to affect the composition of *sewage very materially*. The Rivers Pollution Com-

missioners found the average composition of sewage to be somewhat as follows :—

Constituent Parts.		Parts per Million.	
		Water-closet Towns.	Midden Towns.
Total Solid Residue		1369	1215
Suspended Solids	Organic	205	213
	Mineral	242	178
	Total	447	391
Dissolved Solids		722	824
Organic Carbon		47	42
Organic Nitrogen		22	20
Ammonia		67	54
Total combined Nitrogen		77	65
Chlorine		107	115

From other sources it appears that the phosphoric acid amounts to about 25 and the potash about 15 parts per million. These proportions are, of course, liable to very wide variation.

It is calculated that in an ordinary population $2\frac{1}{2}$ ounces of solid excreta and 40 ounces of urine, together containing 150 grains of nitrogen,* are yielded per person per day, taking an average of all ages. This corresponds to about 10 lbs. of ammonia per annum, and a theoretical manurial value of 6s. 8d., to which the constituents of the urine contribute six-sevenths, and the fæces one-seventh only. The manurial value of sewage is dependent upon the combined nitrogen, potash, and phosphoric acid. The annual amount of sewage per head of population may be taken as 100 tons, the theoretical money value as manure being about 17s., to which the dissolved matters contribute 15s., and the suspended matters only 2s. Sewage also contains variable quantities of household waste, rain and storm water, grit, gravel, sand, and, in some localities, manufacturing waste products.

* *This is Parkes'* estimate. Frankland's estimate, for adult males, is *250 to 300 grains.*

Bacteria in sewage are chiefly denitrifying and decomposition organisms. Houston found in London crude sewage at the Barking outfall an average of nearly 4,000,000 micro-organisms per c.c., and in one sample of domestic crude sewage 28,000,000. All kinds of species are present (bacilli preponderating) and there are many spores. The most common are *B. coli* (600,000 per c.c.), the *Proteus* family represented by the "sewage proteus" (100,000 per c.c.), *B. enteritidis sporogenes*, sewage streptococci, and liquefying bacilli. Pathogenic organisms also occur, but, owing to the struggle for existence, rapidly disappear. All the organisms required for bacterial assimilation are present in the sewage itself. The artificial bacterial treatment of sewage is an application of the principles of nitrification as stated by Schlœsing and Muntz.

Disposal of sewage.—In rural districts the household and other liquid refuse, if not turned into a ditch or watercourse, is usually conducted to a cesspool or collecting tank, from which it is periodically removed and used as manure. The former plan is bad in every respect. The latter is permissible only if the cesspool is made water-tight and properly covered and ventilated, regularly emptied at suitable intervals, and situated at a sufficient distance from any house, road, or water supply. The annotated Model Bye-laws require a minimum distance of 50 feet from any dwelling, and 80 feet from any water supply. Sometimes the sewage is led to a pit, or "dumb-well," in porous soil, the solids being removed at intervals and the liquids escaping into the ground. This practice is dangerous if the pit is near to dwellings or water supplies, and is not free from risk of polluting water in any case. Simple irrigation is free from objection if well managed, even on the small scale. "Subsoil irrigation" may

work well when the conditions as to soil and fall are suitable; the drainage is conveyed into a branching system of loosely laid agricultural pipes, which allow it to escape into the subsoil. The pipes are laid about a foot or more beneath the surface. It is often necessary to relay them at intervals, owing to deposit of grease and other obstructive matter, but this may to some extent be prevented by the use of flush-tanks and grease-traps at the house-end of the drain.

The chief point is to expose the sewage to the influence of growing vegetation, not so much for the sake of utilising it as of rendering it innocuous. Sewage applied to the surface is partly absorbed by vegetation, partly oxidised (nitrified) in the superficial layers of earth. The sewage passed into leaking cesspools or dumb-wells escapes both forms of purification, and simply pollutes the soil and the subsoil water.

The disposal of town sewage may be effected in a variety of ways. The oldest and simplest is to pass it without purification into natural watercourses, a plan still common. The sea affords a ready means of disposing of the sewage of coast towns. It is allowed to escape only with the ebb tide, and reflux is prevented by valves. If it is conducted by pipes sufficiently far out to sea, it may not be washed back by currents or by the returning tide to foul the shore. Such a degree of success is far from being the rule, and there are the further objections that the removal of sewage by this means is only intermittent, and that the sewage is (at best) wasted. To a certain extent organic impurities in streams are got rid of by oxidation and by the growth of plants and other organisms, but this possibility of subsequent partial purification cannot justify the gross pollution of a stream at any given point. The purification can rarely be complete, and in no case can there be any

certainty of the destruction of specific pollution, a consideration that is especially important when the stream furnishes the water supply of districts lower down.

The alternative is to purify the sewage with the object of oxidising or retaining its dissolved and suspended impurities, and allowing only the water (with, at most, harmless dissolved matter) to pass into watercourses or the sea. This may be done by *precipitation*, *filtration*, *irrigation*, or *bacterial treatment*.

Precipitation processes aim at throwing down the organic matter chemically or mechanically, by the addition of a reagent to the sewage. For the most part their success in this respect is only partial, and they leave the ammonia and chlorides in the effluent. The reagents, dissolved or suspended in water,* are added to the raw sewage either in the sewers (Scott's and Conder's processes) or more usually in a conduit at the works. In either case the flow of the reagent is regulated as required, and it becomes thoroughly mixed with the sewage before entering the tanks. The settling tanks are large and are usually worked in series, the overflow from each into the next being over a broad shallow sill, so that only the comparatively pure upper water may escape. The current being very slight in the tanks, suspended matters are gradually deposited, accumulating at the bottom in the form of sludge, which is periodically cleared out, dried, and sold as manure, or dug into the ground, or (in Scott's process) burnt into cement. A similar subsidence takes place if no precipitant is used, but the dissolved organic matter remains in solution, and the settlement of the suspended matter is much slower and less complete. A good precipitation process will rapidly clarify the sewage by removing

* *In the alumino-ferric process*, cakes of the reagent are laid in the *sewage current*, and dissolve slowly.

all, or nearly all, the suspended impurities, and will, moreover, carry down a greater or less part of the dissolved organic matter. The effluent will be fairly clear, but will contain the chlorides and certain other salts, ammonia, and more or less of the dissolved organic matter. It is therefore necessary to subject the effluent to further treatment, that is, to filtration, in order to oxidise the remaining organic matter.

Among artificial filtering media, employed after precipitation, are various forms of carbon, ferruginous materials, and burnt "ballast." All of these, like land filters, serve mainly as a nidus for the aërobic nitrifying organisms, and their efficiency depends largely upon proper management, and especially due aëration. The flow should be intermittent and not too rapid. Coke is widely used. Garfield finds that fine coal filters give excellent results, and possibly the non-porosity of the particles is an advantage. Ferruginous materials include "polarite," "magnetite," and "magnetic carbide"; they should be covered with a layer of sand, renewed at intervals.

Precipitation affords no guarantee of the removal of microbes, pathogenic or otherwise.

Many of the precipitation processes described in text-books have been abandoned on account of cost or want of efficiency, and have now only a historic interest. Lime is by far the most generally employed, either alone or in conjunction with other reagents. It has been used together with clay (Scott), calcium phosphate (Whitthread), magnesium chloride and tar (Hillé). The "Amines" process consists in adding lime together with a little herring brine. The latter, by virtue of the trimethylamine and other ingredients (aminol), acts as an antiseptic. The effluent does not decompose, and yields no microbes on cultivation. The precipitation is rapid. Lime with ferrous sulphate, ferric chloride, or aluminium sulphate gives a bulky precipitate of the respective hydrate, which entangles and carries down organic matter with it. Crude aluminium sulphate, made by acting upon clay or shale with sulphuric acid, is Anderson's (and also Bird's) precipitant; and sulphuric acid with mineral phosphate of alumina is the basis of Forbes and Price's process. Spence's "alumino-ferric" contains a very

small proportion of iron salts. Sillar's A B C process consists in adding alum, blood, clay, and charcoal.

Another precipitant is "ferrozone," made by acting with sulphuric acid upon "polarite," described as a specially prepared ore of iron. The effluent is filtered through a bed of polarite. Another iron process, differing from the rest in being applied at the *head* of the sewer or house drain, is Conder's, in which a regulated quantity of ferrous sulphate is added constantly and automatically by means of a stream (of water or sewage) passing through a vessel ("ferrometer") containing crystals of ferrous sulphate. It seems to be successful in preventing decomposition and effluvia, and in keeping the drains free from deposit. A saturated oxy-chloride of iron is used as a precipitant, in the ordinary way, in the "Clarine" process. Use is sometimes made of chalybeate waters for precipitation purposes.

Webster's electrolytic process adds iron indirectly. The sewage is made to flow through a series of tanks in which it is exposed to a powerful electric current passing between electrodes consisting of iron plates. Ferrous hydrate is continuously formed, and reacts at once in the nascent condition upon the sewage, causing a rapid and fairly complete precipitation of solids. A clear and slightly greenish effluent results, which is remarkably free from microbes and has little tendency to secondary putrefaction. In the Hermite process electrolysed sea-water is employed.

In the black ash process, a waste product from alkali- and soap-works is used as a precipitant. This refuse contains calcium sulphide, which by exposure to air is partially oxidised into calcium sulphite and hyposulphite. The prepared black-ash is used together with lime.

Lime processes in general yield an alkaline effluent, which has a tendency to "secondary decomposition." A lime effluent that is bright and clear on leaving the works will often be found to become turbid and offensive, if its run can be traced for a few hundred yards, without excessive dilution by other water.

Filtration of sewage may be adopted either alone or as a supplement to a precipitation process.* The filtering media employed are land, certain ferru

* *E.g.* —Closed septic tank and contact beds. Open septic tank and contact beds. Chemical treatment, subsidence tanks, and contact beds. Subsidence tanks, and contact beds. Contact beds alone. Open septic tank. Chemical treatment, and subsidence tanks. Subsidence tanks.

ginous materials, and coke or other matter containing carbon. By filtration it is sought to remove the suspended matters, and to oxidise the organic matters and ammonia. The effluent should contain only chlorides and other dissolved mineral salts and nitrates, but some free and albuminoid ammonia is always found upon analysis.

Intermittent downward filtration may be defined as "the concentration of sewage at short intervals, on an area of specially-chosen porous ground as small as will absorb and cleanse it, not excluding vegetation, but making the produce of secondary importance," the flow of sewage being suspended from time to time in order to allow the filter to become charged afresh with oxygen from the air.

Land filtration requires a porous soil, underdrained by porous pipes at a depth of four to six feet. The sewage is distributed over the surface by means of branching carriers or trenches, controlled by sluices, so that each portion of the ground in turn receives the sewage for a few hours, and each has intervals of rest. The soil is raised in ridges, upon which vegetables are grown, the sewage flowing along the furrows between the ridges. The utilisation of the sewage is a minor consideration; but vegetation is useful in absorbing and assimilating the organic matter. Land-filters planted with osiers (osier-beds) are sometimes employed for the purification of village sewage, or for the occasional treatment of storm waters that cannot be dealt with otherwise. The osiers absorb water and sewage matter freely; but constant care is needed to prevent choking of the surface-soil, or of the subdrainage.

Broad irrigation "means the distribution of *sewage over* a large surface of ordinary agricultural *ground, having* in view a maximum growth of vege*tation* (consistently with due purification) for th

amount of sewage supplied." For broad irrigation, as for simple filtration, the soil should be porous, but not necessarily underdrained. The sewage is distributed over each portion of the ground intermittently, by means of branching carriers, which pass along ridges of soil twenty or thirty feet apart, or along contours of slopes, and are controlled by sluices. At intervals the sewage is turned into each carrier, and overflows down the slope. The sewage is screened before distribution, unless it has been subjected to preliminary filtration or precipitation. The effect is similar to that of simple intermittent downward filtration, of which, indeed, this is only a modification. The nitrates may, however, be reduced by vegetation. The crops grown upon "sewage-farms" are very heavy. Italian rye-grass is well adapted for the purpose, since it grows rapidly and absorbs much sewage, but many other forms of vegetation can be substituted. If the land is limited in area, provision may be made for temporary excess of sewage after heavy rainfall by setting aside a portion of the ground as a land-filter.

It is usual, in cases where the approval of the **L.G.B.** is required, to provide at least an acre of land for each 300 of population if broad irrigation is adopted; or an acre for each 1,000 if there be either broad irrigation coupled with precipitation or intermittent downward filtration through underdrained land; or an acre for each 2,000 if precipitation is followed by land filtration. It is considered necessary to secure land, to the above extent, even if artificial filters are provided.

Apart from the action of vegetation, the purifying effect of different soils shows considerable variation. The Rivers Pollution Commissioners found that a cubic yard of chalk or sand effectually purified 5·6 gallons of sewage per diem applied intermittently; while a

sample of loam purified 9·9 gallons under the same conditions. Peat had slight purifying power at first, but improved with repeated use, owing, perhaps, to increase in the nitrifying organisms. Intermittent filtration through suitable soil removed 70 per cent. of the organic nitrogen, and upwards of 80 per cent. of the organic carbon. On the whole it may be said that peat and stiff clay lands are generally unsuitable for the purification of sewage, that their use for this purpose is always attended with difficulty, and that where the depth of top soil is very small, say six inches or less, the area of such lands which would be required for efficient purification would in certain cases be so great as to render land treatment impracticable.

The first Sewage Commission (1857-1865) reported that "the right way to dispose of town sewage is to apply it continuously to land, and it is only by such application that the pollution of rivers can be avoided."

A further Commission appointed to inquire into the best means of preventing the pollution of rivers (1868-1874) reported with regard to chemical precipitation, intermittent filtration, and broad irrigation: (1) All these are to a great extent successful in removing polluting organic matter in suspension, but intermittent filtration is best, broad irrigation ranks next, and the chemical precipitation processes are less efficient. (2) For removing organic matters in solution the processes of downward intermittent filtration and broad irrigation are greatly superior to upward filtration and chemical processes.

Another Commission (1882-1884) appointed to inquire into the system under which London sewage was discharged into the Thames, whether any evil effects resulted therefrom, and if so, what remedial or preventive measures could be applied, found that evils did exist "imperatively demanding a prompt remedy," and that by chemical precipitation a certain part of the organic matter of the sewage would be removed. They reported, however, "that the liquid so separated would not be sufficiently free from noxious matters to allow of its being discharged at the present outfalls as a permanent measure. It would require further purification, and this, according to the present state of knowledge, can only be done effectually by its application to the land."

Experience has shown that with careful management a properly constructed sewage-farm can be carried on without nuisance or injury to the health of the surrounding population; but if the land becomes waterlogged from accident, defect, or inattention, grave nuisance may readily result. It was at first feared that parasitic and other diseases in animals and man would be promoted by the use of the produce of sewage-farms as food, but no such result has been observed.

Bacterial Treatment.—Biological methods of sewage purification have of late been more thoroughly studied, with important results. The oxidation effected by the aerobic organisms has been increased (1) by supplying oxygen more freely by artificial means on a *contact bed;* that is, a specially prepared filter charged intermittently with sewage which is allowed to rest for a time upon it, and (2) by previously subjecting the sewage to anaerobic fermentation, the effect of which is to bring about more complete solution of the organic matter and render it readily oxidisable. For the second purpose the "septic tank" has become widely used. Lowcock blows air into the interstices of the filter by means of perforated pipes. Scott-Moncrieff passes sewage, after anaerobic treatment, through a vertical series of shallow filter-boxes, with intervening air-spaces, and finds that there is a differentiation of the microbes in the successive stages, so that if the sequence of the filters is changed the purification is for a time arrested, and the effluent becomes foul. Ducat's tank is filled with porous material, such as burnt ballast finer below and coarser above; it is ventilated by field-pipes passing through at various levels, and the walls of the tank are for the most part built of open drain-pipes, placed transversely so as to admit air freely; it is claimed that the tank can be used continuously without rest, and that no further

treatment is necessary. Dibdin employs a tank filled with coarse burnt ballast; the sewage is run in and allowed to stand for two hours, after which it is slowly run off—to filters, or to a second tank with finer materials—and the tank is allowed several hours' rest for aëration.

Bacterial purification depends upon two main groups of organisms, namely, those that are able to break down and liquefy solid organic matter, and those that deal with it when in solution; but no strict line of demarcation can be drawn between them. Different systems depend upon an anaërobic action (Cameron, Scott-Moncrieff, etc.) or aërobic (Dibdin, Fowler, etc.), or a mixture of the two. Whatever system is used, the two great agencies of breaking down and oxidation must be allowed ample opportunity. Two examples are furnished in Cameron's *septic tank* (anaërobic) at Exeter and many other places, and in the *multiple contact bacteria-beds* (aërobic) at the Davyhulme Works, Manchester.

For contact beds burnt clay, coke, clinker, cinders, or various forms of gravel may all be efficient media, provided there is ample aëration and porosity. The necessary organisms exist in the sewage, but require abundant oxygen. To assist in maintaining aëration the surface should be raked over from time to time. Obstruction by frost rarely occurs, the temperature of the sewage being from December to April about 55·5° F. Frequent and prolonged periods of rest are necessary; without them the beds become clogged, and eventually inactive because lacking in aërobic bacteria. The sewage applied to the bed should be as far as possible uniform in consistence and freed from suspended matters by sedimentation. Any suspended matter *not so removed* should be retained as far as possible *on the surface* of the bed.

Fowler concludes that the bacterial process is best conducted in three stages :— (*a*) settlement and screening out of the grosser solids ; (*b*) anaerobic decomposition in the septic tank ; and (*c*) oxidation on bacteria beds. He summarises the conditions of the successful working of contact beds as the result of the Manchester experience as follows :—

(1) The bed should be worked very slowly at first, in order to allow it to settle down and the bacterial growths to form. In this way there will be less danger of suspended matter finding its way into the body of the bed, while the material is still loose and open. (2) The burden should not be increased till analysis reveals the presence of surplus oxygen, either dissolved or in the form of nitrates in the effluent. (3) Analyses of the air in the bed may usefully be made from time to time during resting periods. (4) The variations in capacity should be carefully recorded. If the capacity is found to be rapidly decreasing, a period of rest should be allowed. (5) Long periods of rest should be avoided during winter, as when deprived of the heat of the sewage the activity of the organisms decreases. If necessary, the burden on the bed should then be decreased by reducing the number of fillings per day, rather than by giving a long rest at one time. (6) The insoluble suspended matter should be retained on the surface by covering the latter with a layer of finer material not more than three inches in depth. The suspended matter thus arrested should not be raked into the bed, but when its amount becomes excessive it should be scraped off. This should be done if possible in dry, warm weather, after the bed has rested some days. By placing the inlet and outlet penstocks as close together as possible, the suspended matter will tend to concentrate in their vicinity, and its removal will be facilitated.

It should be noted that if sewage contains genic bacteria, and is then treated by methods, the effluent cannot certainly to be safer in this respect than the raw and, therefore, effluents should not drinking-water streams, but on to the

Selection of Method.—The cl various methods of purification of

determined largely by local considerations. We have already quoted the findings of the Sewage Commission of 1868 (see page 264). If the sewage is free from manufacturing effluents of injurious character, and if a sufficient area of suitable land can be obtained in a convenient position at a reasonable cost, broad irrigation is entitled to preference as the most rational and economical method of treatment. If there is serious difficulty in obtaining suitable land, simple intermittent downward filtration, or the bacterial treatment, may be preferable; and precipitation processes and artificial filters for still smaller areas may suffice.

Proper construction in the first instance, and careful management afterwards, are essential in every process, and without them nuisance cannot fail to result. It is desirable, for the sake of economy and efficiency in management and supervision, that sewage should be dealt with at as few points as possible. The process of purification is greatly facilitated by the "separate" system of drainage, the volume of sewage being thereby reduced and rendered more constant.

In manufacturing districts the principal difficulty arises in connection with trade effluents. Many kinds of manufacturing refuse if admitted into the sewers interfere with the efficacy of land-filtration, either by clogging the soil or chemically checking the process of oxidation. The latter condition also operates prejudicially in bacterial methods. In such cases a preliminary purification by precipitation is necessary, and it is probable that the effluents of different trades will be found to require different chemical treatment. If they are poured into streams without purification, they cause pollution exceeding in intensity that caused by domestic sewage. For each manufacturer in such a district to deal with his own refuse would entail a very heavy aggregate expense;

and the multiplication of such works is in itself undesirable, since it must increase the risks of mismanagement and failure Still, where trade effluents cannot be received into the sewers, the responsibility for their purification rests with those who produce them. In some cases the difficulty may be overcome by combination among manufacturers, and in others by the provision of a special intercepting sewer. A satisfactory compromise has been reached in some towns by the manufacturers partially purifying the effluents before turning them into the sewers.

The Rivers Pollution Commissioners in 1868 proposed that impurities exceeding any of the following standards should be held to render an effluent unfit for discharge into a river:—

Impurity	Parts per 100,000 in excess of	Other standards.
In suspension—		
Organic matter .	1	Perfect rest in subsidence tanks for at least six hours also required.
Mineral matter in suspension . .	3	
Oily matter in suspension	0·05	Or any film of oil on the surface.
In solution		
Organic matter		
Organic carbon . .	2	
Organic nitrogen .	0·3	
Metals (other than K, Na, Ca, Mg). . . .	2	
Arsenic . . .	0·05	
Chlorine (free, after addition of H_2SO_4) .	1	
Sulphur as sulphides	1	
Acidity (as HCl) .	2	
Alkalinity (as NaHO)	1	
Colour		Any … depth… exam… in a

The following have been su… *conditions* which an effluent ough… *must contain* practically no s…

(*b*) it must not contain in solution a quantity of organic matter sufficient to absorb much oxygen from the stream into which it is discharged; (*c*) it must not be liable to putrefaction or secondary decomposition; (*d*) it must contain nothing inimical to microbial growth and activity, therefore it must not be treated with strong antiseptics; and (*e*) it must not contain pathogenic organisms.

CHAPTER X.

DISPOSAL OF THE DEAD.

THE daily average of deaths in England and Wales is about 1,500. The disposal of this enormous number of dead (many of whom have died of infectious diseases) in such manner as to avoid danger to the living is a sanitary problem which, like many others, has only received due attention within comparatively recent years. The horrible overcrowding of graveyards which prevailed in the early part of last century is now rarely met with, and is only possible in the older grounds which are not subject to modern regulations, and which have not been formally closed by Order in Council. Seymour Haden has shown that if carcases are covered by a foot of suitable earth, the perishable parts disappear inoffensively within twelve months, and speaking broadly it may be said that for every foot of depth below the surface of the soil one year or thereabouts is necessary for resolution. The present practice, however, and even the law, are inconsistent with burial sufficiently shallow to permit of the due action of the nitrifying organisms found only in the upper layers of the soil. The objects of earth burial are further frustrated by the still prevalent use of metallic or heavy wooden coffins.

Burial-grounds. The objects to be aimed at are rapid resolution and complete oxidation or absorption of the products. Hence the soil should be light, finely *porous*, and either naturally or artificially *drained to* a depth of not less than eight feet, so that

"The degree to which the purity of neighbouring wells is endangered by a cemetery, and the distance to which contamination may extend, obviously depend in each particular case upon the relative elevation of the respective sites of cemetery and well, and upon the nature and dip of the intervening strata, so that it would seem impossible to lay down a general rule for all cases. Fissured rocks might allow foul matters to traverse considerable distances, while the interposition of a bed of clay or a water-tight fault would shut them off, or the passage through an aerated stratum of finely divided earth would oxidise and destroy them on their way. A dangerous state of things occurs when graves and wells are sunk near together in a shallow superficial water-bearing stratum of loosely porous nature resting on impervious clay. From experiments made at Dresden by Professor Fleck . . . it would seem that the degree to which wells so situated are liable to pollution is greater when the surface of the subsequent clay bed is horizontal than when it is sloping, even though the slope be towards the well. In the latter case the ground-water is on the move; in the former it is stagnant, and hence the foul matters are concentrated in a smaller volume of water; just as the water of a stagnant pool is more liable to become foul than that of a running stream. It does not appear, however, that the risk to which wells are exposed from the proximity of a properly managed cemetery is in ordinary cases great. A leaky cesspool is a far greater source of danger than a grave. The solid and liquid excretions voided by a human being in the course of a year amount to several times the weight of his body.

"The State Board of Health of Massachusetts . . . give a series of analyses of water from wells in the neighbourhood of cemeteries. Of seven wells in sandy and gravelly soil, varying in depth from 4 to 17 feet, situated at distances respectively of 60, 50, 10, 100, 200, 75, and 100 feet from the nearest grave, and having no other sources of contamination at hand, one only showed undoubted evidence of contamination; this was 10 feet from the nearest grave, the most recent interment, made five and a half months before, being 35 feet distant; the three purest wells were those at 60, 50, and 75 feet distance. The chemical characters by which it may be inferred that the contamination of a particular water is derived from decomposing bodies rather than from sewage, are a high proportion of nitrogenous organic matter and ammonia, or if oxidation have *proceeded* further, of nitrates and nitrites, relatively to the *amount of chlorides* present, and also the presence in notable *quantity of phosphates.*" (**L.G.B.** *Memorandum*, 1880.)

Both urban and rural authorities are enabled by the P.H. (Interments) Act of 1879 to provide cemeteries for their districts, and must do so if required by the **L.G.B** The cemetery need not be within the district of the **S.A.** The **L.G B.** point out, in a memorandum issued in 1879, that it is incumbent upon the **S.A.** to take action

1. Where in any burial-ground that remains in use there is not proper space for burial, and no other suitable burial-ground has been provided.

2. Where the continuance in use of any burial-ground (notwithstanding there may be such space) is, by reason of its situation in relation to the water supply of the locality, or by reason of any circumstances whatsoever, injurious to the public health.

3. Where, for the protection of the public health, it is expedient to discontinue burials in a particular town, village, or place, or within certain limits.

The necessity may also arise from unsuitability of the site or of the subsoil, or from inconvenience of access from populous parts of the district.

If it is desirable, upon the above or other grounds, to close any existing burial-place, a representation must be made to the Home Secretary for the purpose of obtaining an Order in Council to that effect, under the provisions of the Burial Act of 1853.

In excavations for new buildings in cities not infrequently skeletons and coffins are met with, which it is required to remove. For removal from one consecrated ground to another a faculty from the Bishop of the diocese may suffice, but otherwise application must be made to the Home Secretary, from whom "a licence for the removal of human remains," under the Burial Act, 1857 (s. 25), may be obtained. The remains are then suitably re-coffined in boxes and re-interred in a burial ground where burials may legally take place.

Interments underneath or within the walls of any church built after 1848 are forbidden by the P.H. Act of 1848 (s. 83; re-enacted by the P.H. Act, 1875). No buildings must be erected upon any disused burial-ground, except for the purpose of enlarging a place of worship (Disused Burial Grounds Act, 1884).

Cremation.—In a crematorium of modern construction a body of average weight is reduced to about 3 lbs. of inorganic ash within two hours. The usual fuel is coal and coke, but Fradet recommends gas. In either case, a ventilating shaft with pilot fire at its base is necessary. The chief objections to cremation are that the soil is deprived of the organic matter that would otherwise be returned to it, that it involves an unnecessary waste of the world's limited stock of combined nitrogen, and that the impossibility of exhumation would increase the facilities for concealing homicide. The first objection has no great weight at present, since little attempt is made to utilise burial-grounds by cultivation. The last is, however, more serious, and cannot be regarded as satisfactorily met by the proposition of minute and detailed autopsy in every case. Half a million examinations annually, each sufficiently detailed to cover every known poison and every possible wound, would be impracticable, especially as the result must, in the vast majority of cases, be negative. The discovery of organic disease would not by any means necessarily exclude the possibility of foul play. Some few poisons, such as copper, might be detected in the ashes, but organic and volatile mineral poisons would be dissipated by cremation. It is true that under present conditions occasion for exhumation rarely arises, but the possibility of it may to some extent act as a check upon crime. The Cremation Act, 1902, empowers Burial Authorities (Burial Boards or other local authorities

maintaining cemeteries) to provide and maintain crematoria. The plans and site must be approved by the **L.G.B.**, and the completion must be notified to the Home Secretary before any cremation takes place. No crematorium may be built within 50 yards of any public highway, within 200 yards of a dwelling-house (except by consent of owner), or within the consecrated part of a burial-ground.

Home Office Regulations of 1903 impose conditions as to maintenance, inspection (by Home Office and **L.G.B.**), disposal of ashes, and the further points stated below. Cremation is not allowed if the deceased has left written directions to the contrary, or if the body has not been identified. There must be (*a*) medical certificates as to the cause of death from two registered practitioners (one being the medical attendant and the other a practitioner of at least five years' standing who (1) is specially appointed by the Authority for the purpose, or (2) is **M.O.H.**, Certifying Surgeon under the Factory Act, or Medical Referee under the Workmen's Compensation Act, or (3) is physician or surgeon to a public general hospital with at least 50 beds), or (*b*) a certificate given after post-mortem examination by a skilled pathologist, or (*c*) a certificate given by a coroner after inquest. In certain circumstances (*b*) and (*c*) become essential.

A Medical Referee must be appointed by the Authority, and a deputy to act for him in his absence or in cases where he is the medical attendant. His certificate that all the conditions have been fulfilled is necessary before any cremation can take place, but certain relaxation can be allowed by him in exceptional cases (persons dying of plague, yellow fever, or cholera, on ship or in an isolation hospital; still-born children; bodies exhumed after burial for more than a year). Other modifications can be made temporarily by Order of the Home Secretary on application of the **S.A.**, during an epidemic or for other sufficient reason.

CHAPTER XI.

ANIMAL PARASITES.

In addition to the pathogenic bacteria, belonging rather to the vegetable than the animal kingdom, the human body is liable to invasion by a number of parasitic animal organisms, among which the following are the most important.

Protozoa are unicellular animals, little more highly developed than some of the bacteria. They are usually divided into four classes: Rhizopods, Sporozoa, Flagellates, and Infusoria. The last named group, which includes *paramœcium*, need not be further considered. It is only recently that the relation between these protozoa and human disease has been demonstrated with any clearness.

The Rhizopods are the lowest group, and comprise the amœbæ which move by pseudopodia and reproduce themselves by simple division. Many kinds of amœba occur in the human intestine, some being genuine rhizopods in vegetative stage, others being amœboid stages of higher forms. Two of the forms (*Gymnamœbæ*) are human parasites, namely, the *amœba coli* (or as it is termed by Schaudin, *entamœba*) and the *amœba dysenteriæ* (*entamœba histolytica*). The former appears in the excreta of 20–50 per cent. of healthy persons, though it is not easy of detection. The latter is possibly the cause, wholly or partly, of dysentery, as commonly occurring in the tropics.

The Sporozoa are so called because at one stage of *their life history* the individual breaks up into a number

of minute reproductive bodies resembling the spores of fungi, often encysted. This group includes the *gregarines* which inhabit the digestive tract of crustaceans, the *coccidia* which are intestinal parasites in birds and in animals, and the *hæmosporidia*, or parasites of blood corpuscles, such as the protozoa of malaria. The life history comprises alternation of generations and change of host. Once the sexually-produced reproductive body or spore finds its way into a suitable host it attains its full size and then splits up into individuals which carry on the cycle.

Coccidium oviforme produces coccidiosis or psorospermosis in rabbits and other animals. *Pyrosoma bigeminum*, the cause of Texas fever in cattle, which is transmitted by a tick, is a closely allied organism.

The Flagellates include the *Trypanosomes*, which cause various diseases of horses, bovines, rodents, etc. They have now been shown to be the cause of certain diseases of man, such as sleeping sickness, and are conveyed by a fly, *Glossina palpalis*. A trypanosome has a long spermatozoon-like body fringed on one side with an undulating membrane prolonged at the anterior end into a flagellum. The body possesses a large nucleus. One species, at least, has been cultivated on blood agar. The organism passes through various stages in its life cycle, and a connection has recently been established between the malaria parasite and the trypanosome. It is probable also that a relation exists between both of these parasites and the higher bacteria known as Spirochœtæ; indeed they may only be forms of the same organism.

The next group of animal parasites infesting man are the Insecta and the Arachnida. Among the former are fleas, bugs, lice, the *Pulicidæ*, and the larvæ of certain flies; among the latter are the mites, ticks, and *Pentastomata*. More important are the parasitic

worms, which may be divided broadly into two groups as follows :—

1. The flat worms (Platyhelminthes), which are usually sub-divided into the Cestoda or tapeworms and the Trematoda or flukes.

2. The round or thread worms (Nemathelminthes) or Nematoda. This group includes the common thread worm (*Oxyuris vermicularis*), the common round worm (*Ascaris lumbricoides*), and the various forms of filariæ and ankylostoma.

Tæniada.—It has been said that as many as a dozen forms of tapeworm occur in man. This species of Cestoda passes through two distinct phases, in two different hosts. In one, the head, or *scolex*, together with a cystic expansion, is embedded in muscle and other solid tissues; in the other, the *strobilus* or tapeworm occupies the alimentary canal of some other animal. If the flesh containing tænia cysts (*cysticerci*) is eaten by another animal, the scolex reaches the alimentary canal of the new host, loses its cyst, and attaches itself to the wall of the intestine. It then develops from the caudal end joint after joint of *proglottides*, square or oblong flat segments, each of which is provided with double sexual organs. The chain of proglottides may attain a length of many feet. Ova are produced in the segments, and escape with the excreta of the host if the segments rupture or become detached, or if the whole of the tapeworm is expelled. Some of the ova are swallowed by a herbivorous host, and the embryo then bursts its shell, makes its way from the intestine to the solid tissues of the host, and after developing anew into a *cysticercus*, remains passive until it is devoured by a carnivorous animal, or perishes.

Man is subject to tapeworms, and more rarely to *their cysticerci. Tænia solium*, one of the commonest *of human* tapeworms, attains a length of seven to ten

feet or more, consisting sometimes of 700 to 800 proglottides. The head is about the size of the head of a pin, and bears four suctorial discs, and a double circle of hooklets surrounding a prominence or *rostellum.* It attains its full development in three or four months, but may remain in the intestine for years. The ovum is spherical, $\frac{1}{750}$ inch in diameter, and has a thick brown shell; the embryo has six hooks. The cysticercus or bladder worm of the *Tænia solium* is termed *Cysticercus cellulosæ.* It affects the pig, and more rarely man; in the latter it lodges in the muscles, connective tissues, brain, eye, and serous membranes, and attains its full development in about $2\frac{1}{2}$ months. The cyst reaches the size of a pea, or even a marble, the head or scolex has a double crown of hooklets. In pigs it constitutes the affection known as "measles," and the consumption of uncooked "measly pork" is the chief source of *Tænia solium* in man.

Tænia mediocanellata is more common than *Tænia solium*, and somewhat resembles it, but its length is greater (20 ft.). The head is about $\frac{1}{15}$ inch in diameter, and has four suckers, but no rostellum or hooklets. The eggs are oval, the short diameter being about $\frac{1}{850}$ inch. The *Cysticercus tæniæ mediocanellatæ*, or *Cysticercus bovis*, is an oval vesicle smaller than the *Cysticercus cellulosæ.* It consists of a cyst, and a scolex identical with the head of the tænia itself. It occurs in the flesh of cattle and produces "beef measles."

Bothriocephalus latus.—This tænia attains a length of 24 feet or more. The head is ovoid, $\frac{1}{10}$ inch long, and has two longitudinal grooves or suckers, but no hooklets. The body is ribbon like and may have as many as 3,000 segments. The eggs are oval, about $\frac{1}{375}$ inch shorter diameter, and open by a lid at one end. The cysticercus is found in pike, turbot, perch.

other fish. The tænia is met with principally in the Baltic countries (Russia, Poland, Sweden) and in Switzerland. It may, perhaps, gain access to the alimentary canal by means of drinking-water, as the embryo is ciliated, and is found in river water.

Tænia echinococcus affects the dog and wolf only. The head resembles that of *Tænia solium* in presenting a rostellum surrounded with a double row of hooklets and four suckers, but it is only $\frac{1}{100}$ inch in width. There are four segments only, and the whole adult tapeworm is about 2 inches long. The eggs are spherical and contained only in the terminal or reproductive segment. Its cysticercus is a dangerous human parasite affecting the liver and various other parts of the body under the name of *hydatid*, which occurs more frequently in Iceland and Australia than in Great Britain. Unlike other cysticerci it increases indefinitely in size, becoming sometimes a large cyst; it also forms within itself secondary cysts, some of which ("brood-capsules") contain one or more scolices (*echinococci*) and remain minute, while others, containing no scolex, enlarge and form "daughter cysts," which may in turn produce new cysts by gemmation. After death the scolex or echinococcus resembles the head of the tænia, but during life it is retracted into a depression, and thereby turned inside out. Hydatids may continue to grow for an indefinite number of years, and are spread among men and animals by affected dogs.

Tænia nana is occasionally met with in England.

Trematoda or flukes furnish two human parasites, the *Bilharzia Hæmatobia* and the *Distomum hepaticum.*

Bilharzia hæmatobia is believed to be the cause of a form of intermittent hæmaturia endemic in Egypt, South Africa, and elsewhere. The parasite is about $\frac{1}{4}$ inch long, and infests the veins of the large intestine,

bladder, ureter, and pelvis of the kidney. It causes small patches of inflammation along these tracts, and the urine frequently contains blood and the ova of Bilharzia. The ureter may be obstructed. Dysenteric symptoms occasionally occur owing to the presence of the parasite in the veins of the intestine. The ova are about $\frac{1}{185}$ inch long, and have a sharp projecting spine at one end, not quite in the longitudinal axis. The parasite probably gains access to the human body through water, either by drinking or by direct infection of the urinary and alimentary tract during bathing. The *larva* becomes encysted in the body of a minute aquatic crustacean. (*Sonsino*.)

The common liver fluke or *Distomum hepaticum*, which produces "liver-rot" in sheep, is shaped like a diminutive sole and is about an inch in length. It may infect persons consuming affected livers, and may be found in the tissues, and particularly in the portal system.

Nematoda.—The common round worm, or *Ascaris lumbricoides*, affects man and other animals. Its habitat in man is chiefly the small intestine. It is pinkish in colour, and tapers to each end. The male is about 6 inches long, the female 12. The ova, enormous numbers of which are discharged, are oval and nodulated, and measure about $\frac{1}{460}$ inch in least diameter. It is believed that the ova develop only in an intermediary host. The threadworm, *Oxyuris vermicularis*, is much smaller, the female measuring about half an inch in length, and the male about a quarter of an inch. They occur in enormous numbers, chiefly in the rectum. The ova are unsymmetrical but oval, their short diameter being $\frac{1}{1000}$ and long diameter $\frac{1}{500}$ inch. The origin of threadworms is uncertain, but it is probable that they are occasionally disseminated by means of drinking-water.

The adult *Ankylostoma*, which is about half an inch

long, inhabits the upper part of the jejunum in man, *A. duodenale* being found in Europe and the tropics, and *A. americanum* in the United States.* It possesses no intermediate host, and there is no sexual generation outside the host. The infection of each host (man, sheep, etc.) is specific for each parasite. The adult alone is infective, the eggs and young larva being non-infective. The fresh ova are characterised by a thin, clear, colourless shell of oval form, encasing greyish contents divided by segmentation, and eventually becoming a *morula* before the emergence of an active vermiform embryo (in 18 hours). From the fresh egg the encapsuled larva appears in 4 or 5 days or longer. The second period of growth within the host from the encapsuled larva to the adult occupies about 5 weeks. The encapsuled larva is capable of prolonged saprophytic existence under favourable conditions. The eggs are killed in about 24 hours at 40° C. or at zero, and below 13° C. they will not hatch. Moisture and free oxygen are necessary for development of ova after expulsion from the body.

Ankylostoma obtains access to man's intestine by the mouth and through the unbroken skin through the hair follicles as encapsuled larva (*Loos*). From the skin it is carried by the blood stream to the lungs, up the trachea and down the œsophagus to the alimentary tract, in which the parasite attaches itself to the villi of the jejunum, abstracting blood and producing hemorrhages. The typical result of infection is anæmia, sometimes associated with dyspeptic conditions. Many persons harbouring the worm, however, suffer from no symptoms of disease at all. Dobson found eggs in the excreta of 75 per cent. of the natives of Assam; and Boycott found them in

* This nematode has also been termed *Sclerostoma duodenale*, *Dochmius duodenalis*, and *Strongylus duodenalis*.

100 per cent. of workers in certain Cornish mines, although not more than 10 per cent. of the men were actually ill. The healthy worm carrier is probably one of the chief factors in dissemination, and may continue to discharge ova for years. The disease has long been known under such names as "Egyptian chlorosis," tropical anæmia, or miners' anæmia, but only recently fully described by Haldane as "Dolcoath anæmia." It is now termed *ankylostomiasis*, and is recognised as an endemic disease of warm climates, readily introduced into temperate climates by dissemination of the worm. The effect of temperature operates, however, in cold climates. For instance, Tenholt has shown that in Westphalian mines where the temperature is below 17° C. the cases of ankylostomiasis (anæmia) per 1,000 men employed underground was only 0·6, whereas where the temperature was 20–22° C. it was 2·5, when it was 22–25° C. 11·7, and when above 25° C. it was 39·9 per 1,000. Treatment consists in purgation (calomel), followed by three successive doses of 30 grains of thymol. In Westphalia ethereal extract of male fern is used. Preventive measures are based upon personal precautions against ingestion or skin infection, and of separation of the diseased from healthy persons.

Trichina spiralis attacks rodents, pigs, and many other animals besides man, causing the disease known as trichinosis. It is found in the tissues, and especially in the muscles, in the form of ovoid cysts about $\frac{1}{70}$ inch in length, just visible to the naked eye. Within each cyst is coiled an immature trichina, about $\frac{1}{35}$ inch long. The encapsuled trichinæ may retain their vitality for many years, or may perish and become calcified. If the tissues in which they lodge are eaten, the capsule is dissolved by the gastric juice, and the liberated trichinæ rapidly develop, the male attaining in one or two days a length of $\frac{1}{18}$ inch, the

female $\frac{1}{8}$ inch. Ova are formed and impregnated, and are hatched within the uterus in about a week. The embryos escape, burrow into the walls of the intestine and find their way into the tissues of all parts of the body, where they become encapsuled and form the cysts already described, within a month from the ingestion of the trichinous food.

Trichinosis in man is generally due to the consumption of the imperfectly cooked flesh of a pig suffering from the disease. In Germany, where ham, pork, and sausage are often eaten almost or quite raw, trichinosis is far more common than it is in England. The symptoms commence within a week, with nausea, abdominal pain, irregularity of the bowels, prostration, rapid pulse, and elevation of temperature. The malady usually increases in severity for one or two weeks, and then gradually subsides, but fatal enteritis, peritonitis, or pneumonia may supervene, or the patient may die of exhaustion at any time from the end of the first to the end of the sixth week. Characteristic symptoms attend the invasion of the tissues by the parasites. The muscles become painful, tender, swollen, and stiff, so that the limbs are flexed and motionless. The voice is often hoarse or aphonic, from implication of the larynx. The pain in the limbs differs from that of rheumatism in not affecting the joints, but only the muscles. Œdema occurs early, first in the eyelids and face, next in the hands and feet, and may become general and involve the serous cavities. The other symptoms include increasing prostration and copious perspirations; the temperature may be little above the normal, and if high is irregular and subject to morning remissions. The mortality is sometimes very slight, sometimes 20 or 25 per cent.

Various forms of *Filaria* may infest man, particularly in the tropics, setting up a variety of

pathological conditions, such as abscess, lymphangitis, chyluria, elephantiasis, etc. The species is rarely seen in the adult form, is a hair like parasite, and may attain a length of three or four inches. An immature form, met with in cases of chyluria, is about $\frac{1}{75}$ inch long. The ova are about $\frac{1}{1050}$ inch long, and having no distinct shell, their shape is somewhat irregular The parasite is found chiefly in the East and West Indies, but occasionally in England, even among persons who have never left the country. It abounds in the blood of affected persons during the night (*Filaria nocturna*), but disappears from the circulation by day; by changing the habits of the patient this periodicity can be reversed. Its presence is commonly associated with one of two diseases—chyluria and elephantiasis due to the obstruction of the lymphatics, etc., by the parasite. The former is characterised by periodic attacks, in which the urine becomes milky and upon standing coagulates, but the coagulum soon breaks down and decomposition sets in rapidly. These phenomena have been traced to admixture of lymph with urine, and immature *filariæ* are visible under the microscope. Elephantiasis is attended with enormous enlargement of the greater or smaller part of the trunk or limbs, and especially the legs and generative organs (*E. Arabum*).

Filaria medinensis vel dracunculus, or Guinea worm, is about $\frac{1}{10}$ inch in diameter, and usually one to three feet long. It is endemic in certain tropical regions. The embryos affect minute aquatic crustacea (*Cyclops*), in which they undergo larval development. Later they gain access to the human tissues, but whether by means of drinking water or infection through the skin during bathing is not clear. They burrow in the tissues, especially of the legs, causing large boils and sores.

CHAPTER XII.

INFECTION.

CERTAIN diseases, the number of which is steadily increasing owing to improved methods of observation, are termed specific or infective, and are regarded as due to the invasion of the system from without by a definite "ferment" or poison, which grows and multiplies in the body. In some of them the poison is given off again, and these diseases are therefore infectious, or transmissible from person to person.

Modes of Infection.—It cannot be said that the possible means by which infection is given off have been exhaustively determined in regard to any disease, but certain well-established modes may be mentioned, namely :—

(1) By the *breath*, in small-pox, measles, whooping cough, pneumonia, mumps, typhus, scarlet-fever, and probably the great majority of infectious fevers. Little is known of the distance to which infection can be carried through the air; long ranges seem to be possible in small-pox, and may be suspected in measles and whooping cough ; typhus and plague only infect at short distances, and this is probably true of scarlet-fever.

(2) By *exhalations*, from the skin in typhus, and possibly other diseases, from wounds in pyæmia, erysipelas, and other septic diseases.

(3) By *desquamated particles* of epidermis in scarlet-fever, and pustules in small-pox. These may be carried by currents of air.

(4) By *secretions* and *excretions*. Mucus from the mouth, throat, etc., is infective in diphtheria and

scarlet fever; sputa in tubercular phthisis; saliva in rabies in dogs if not in man. Milk is liable to carry infection (Chapter IV.). The bowel excreta are infective in enteric fever and cholera The urine is also a vehicle of infection in some acute specific fevers, as, for instance, in enteric fever. Syphilis and gonorrhœa are transmitted by means of the specific discharges.

As regards the recipient the mode of infection is also varied. Many diseases are conveyed through the air, and the virus is doubtless inhaled, lodging either on the fauces or in the lungs. Water is known to be able to convey the poison of enteric fever and cholera, and milk that of scarlet fever, enteric fever, and diphtheria, the poison in such cases being swallowed. It is probable that the specific organisms multiply in these media. Experiments seem to show that the acid gastric juice kills microbes that are not in the spore stage, but since the reaction is not acid in the absence of solid food, this safeguard is incomplete, especially as regards water-borne virus. Infective particles carried in *fomites*, *i.e.* in clothing, etc., or conveyed by the hand to the mouth, may be inhaled or swallowed. Mosquitoes carry the malarial poison and that of yellow fever, and flies convey infection, *e.g.* of anthrax, plague, enteric fever, and cholera, to a raw surface, or to milk or other food. An attempt is sometimes made to distinguish as "contagious" those diseases which are not usually transmitted without direct personal contact, but this condition is not absolute, and is favourable to the transmission of any infectious malady. Puerperal fever may be regarded as an example of infection by contact or inoculation A few diseases, of which rabies and vaccinia are typical examples, can only be conveyed by inoculation, that is, by lodgment of the virus in an abrasion of the skin; this is the *ordinary mode* of infection by anthrax and glanders,

although inhalation is also possible. Small-pox, tuberculosis, and certain other diseases are also inoculable. Inoculation may occasionally take place through unbroken skin. This has been shown to be possible as regards virulent cultures of the glanders bacillus if rubbed in. Ankylostoma is believed to gain access through the hair follicles (page 284).

In leprosy the mode of infection is still unknown, although the microbe is now familiar. Even less has been made out in regard to rheumatic fever, the specific nature of which, though probable, still remains open to doubt.

De Novo Hypothesis.—Some authorities believe that certain specific diseases occasionally arise *de novo*, independently of infection from any previous case. This has been alleged more especially as regards relapsing fever, typhus, enteric fever, diphtheria, erysipelas, puerperal fever, hospital gangrene, and septicæmia. The closest examination often fails to reveal any exposure to infection, and occasionally, under favourable conditions, these diseases spring up in localities that have for years been entirely free from them. The tendency of modern research, however, is to find an adequate explanation in infection conveyed by *fomites*, by food, by insects, by air-borne micro-organisms, by lower animals suffering from the same disease, possibly with widely different manifestations, or by aberrant forms or unobserved attacks in man. The supposed logical necessity of a "previous case," that is, of an immediately antecedent *human* case, has lost some of its significance since we have learned to recognise the actual living *materies morbi*, to detect it in air, water, and soil, to cultivate it in artificial media for indefinite periods, to transmit it to lower animals, and to increase or lessen its virulence at will. It is noteworthy that most of the infective diseases suspected of origin *de novo* are filth-diseases,

and due to microbes that can be cultivated outside the living body Further, it has been found that there are non-pathogenic microbes of wide distribution, which in every point except virulence closely resemble the specific microbes of enteric fever and diphtheria; and non-pathogenic bacilli, morphologically similar to anthrax bacilli, have been found to be protective against anthrax. Some authorities regard these harm less microbes as being probably generically identical with the virulent microbes that they resemble, and therefore capable of assuming a virulent character if cultivated under suitable conditions, a view that re-introduces the *de novo* hypothesis in a new form.

Endemics, Epidemics, Pandemics.—Many of the specific diseases, and especially those that have relation to telluric conditions, attach themselves more or less permanently to certain localities, and are termed *endemic;* thus cholera is endemic in the delta of the Ganges, leprosy in parts of Norway small-pox in the Soudan and elsewhere, and in a less marked degree diphtheria, enteric, and scarlet-fever may be said to be endemic in certain districts in England From time to time most diseases of the specific class become widely prevalent over a larger or smaller area, and are said to be *epidemic.* Thus cholera in an epidemic form occasionally spreads westward over Europe, disappearing almost entirely in the intervals. Small pox, scarlet-fever, measles, and other diseases, which are always present in England, assume an epidemic form every few years, locally or in widespread outbreaks. Occasionally a disease diffuses itself so generally over a great part of the globe as to constitute a *pandemic.*

The causes of such outbursts are still imperfectly known They have been attributed vaguely to "epidemic constitution" of the air, to "pandemic waves" *of unknown* nature, and, more intelligibly, to climatic

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and meteorological conditions, accumulation of susceptible persons, facilities for convection or transmission, and (as regards cholera and other "filth-diseases") imperfect sanitation. Scarlet-fever, in temperate climates where it has established itself permanently, tends to become epidemic at intervals of about five years; measles at intervals of about two years. Whooping cough is more irregular than either, but on an average becomes prevalent every second year. Diphtheria shows no very marked periodicity, apart from its dependence upon season, and enteric fever none.

It will be seen presently that the liability to each kind of infection varies in man according to age and sex, as well as locality, climate, season, and surroundings. Similar variation occurs among the different races of men, and still more conspicuously among the different genera and species constituting the animal kingdom.

The more important specific diseases that are common to man and certain lower animals are vaccinia, tuberculosis, anthrax, rabies, tetanus, glanders, actinomycosis, and septicæmia. Influenza ought probably to be added to the list. There is some reason to believe that diphtheria and scarlet-fever affect the cow, and the same may be said of enteric fever. Variolous diseases attack sheep and other animals, but are probably not identical with small-pox.

Incubative Period.—A latent or incubative period intervenes between infection and the appearance of the first symptoms of the disease. It is fairly constant for each disease; but shorter and more uniform when infection is due to inoculation or ingestion, and in rabies is dependent further upon the position of the bite.

Little is accurately known of the changes that occur during incubation, beyond the fact that the

poison is multiplying in some part of the system.* The onset of symptoms is very gradual in enteric fever and a few others, but sudden in the majority. The temperature invariably rises, and the characteristic phenomena of each malady follow with more or less intensity. A rash makes its appearance upon the skin in certain of the infectious diseases, hence termed *exanthemata*; the date of its appearance is constant for each disease within narrow limits, and its distribution and other characteristics are also more or less uniform. The chief exanthemata affecting man are small-pox, varicella, scarlet-fever, measles, rötheln, enteric fever, and typhus. In exceptional cases, the rash, like any other given symptom, may be wanting.

Course of Disease.—As a rule, the specific diseases have a short and definite course, ending in death, or in recovery with or without permanent changes in tissues and organs. Some, however, like syphilis and leprosy, run a life-long course, while malarial diseases tend to recur at regular intervals, or after years of apparently complete recovery. Rabies and some other diseases are almost invariably rapidly fatal, while rotheln, mumps, and varicella are attended with such slight constitutional disturbance that deaths are very rare. The tendency to death may be dependent upon constitutional symptoms such as hyperpyrexia, on local lesions as in enteric fever and diphtheria, on complications in the course of the disease (often really part of the disease itself), or, lastly, on sequelæ affecting important organs.

The intensity of any given disease is subject to

* Concurrence of two distinct zymotic diseases is occasionally observed. Vaccinia and small-pox, measles and whooping cough, measles and scarlet-fever, measles and mumps, whooping cough and chicken-pox, are among the least rare examples. According to Squire, diseases with similar incubation (*i.e.* both long or both short) may run their course independently without interfering with each other, but if two diseases with dissimilar incubation are acquired at the same time, one or the other is delayed.

wide variations. Thus small-pox may be so virulent as to kill the patient before any rash appears, or so mild that only one or two spots, sometimes none, may appear. Scarlet-fever sometimes is malignant and rapidly fatal, in other cases so slight as to escape recognition. As a rule, the type, whether severe or the reverse, holds good for the majority of attacks in a given outbreak, or at all events in the same period of the outbreak; but it is commonly more intense in the earlier than in the later part of an epidemic. As regards purely seasonal variations, however, there is reason to believe that in scarlet-fever, and probably in other diseases also, increased prevalence is associated with diminished average severity, as measured by the proportion of deaths to attacks. Age and sex have an important influence upon severity of attack as well as upon susceptibility, varying with different diseases; thus scarlet-fever, whooping cough, and many others become less and less dangerous to life from infancy upwards, while in enteric fever the reverse is the case. Both scarlet-fever and small-pox are less liable to terminate fatally in females than in males, and the same seems to be true also of influenza.

Protective effect. — An important general characteristic of specific diseases is their tendency in the event of recovery to protect the patient against a subsequent attack of the same disease. This statement must be taken in a modified sense as regards syphilis, leprosy, and the malarial diseases. The protection is perhaps most complete in small-pox, but in this, as in all others of the class, second and even third attacks are occasionally met with. In enteric fever, diphtheria, and influenza the protection is much less marked, and in erysipelas, phthisis, and septicæmia it can scarcely be said to exist. *In all cases it* diminishes with the lapse of time, its

duration being dependent upon the nature of the disease, upon the amount of lesion (in vaccination at all events), and probably upon idiosyncrasy. Klein has shown that protection against anthrax, though real, is very brief in guinea-pigs, and much more lasting in cattle. Fatigue greatly increases the susceptibility of rats to anthrax. The presence of sugar in the tissues (due either to direct injection of sugar, or administration of phloridzin) lessens the resistance to glanders and to suppuration, but not to anthrax or tubercle. There are also examples of the virulence of a pathogenic microbe being intensified by the presence of an otherwise harmless germ: thus attenuated cultures of the specific microbes of pneumonia or erysipelas, too feeble to give rise to any symptoms, can be made to cause an intense attack if along with them is injected a culture (sterilised or not) of a harmless saprophyte, *proteus vulgaris.* It has been thought that an attack of enteric fever lessens or annuls the protective influence of vaccination. Little is known as to any protective power of one specific disease against another, unless vaccinia be regarded as absolutely distinct from small-pox. Erysipelas has been found experimentally to be protective against anthrax. Animals are inoculated with the "attenuated virus" of anthrax, fowl cholera, and other diseases, the object being to obtain protection by means of a mild form of the disease. Inoculation for small-pox, and the Pasteurian prophylaxis against rabies, are examples of similar procedure applied to man.

The Germ theory, broadly stated, affirms that certain specific diseases are invariably associated with the growth and multiplication in the system of corresponding specific microbes, and that these microbes are the actual contagia or causes of the disease. The *evidence is partly* direct, partly indirect.

1. In regard to a few diseases the proof is complete, since—(*a*) a certain microbe is invariably discovered in the blood or tissues of animals suffering from the disease in question; (*b*) this microbe can be cultivated in artificial media, for any required number of successive generations; (*c*) the same disease is reproduced by inoculation of a susceptible animal with the last cultivation; and (*d*) in every such inoculated animal the specific microbe is found, with the same distribution as in animals infected in the ordinary way.*

The third stage (*c*) being as a rule inadmissible as regards man, the complete proof is practically limited to diseases that attack some lower animal. Of those affecting man (as well as lower animals), anthrax and tuberculosis have been fully proved to be associated with specific microbes, and similar complete evidence is forthcoming in respect of many diseases attacking lower animals only.

2. A characteristic microbe is constantly found in the blood or tissues of persons suffering from certain other diseases—*e.g.* relapsing fevers, enteric fever, diphtheria, leprosy, pneumonia, cholera, etc., although the proof of causative relation is incomplete. In several diseases, however, which from analogy are nevertheless believed to be microbial, no specific or characteristic organism has been isolated with certainty. Measles and whooping cough may serve as examples.

3. There is a close analogy between the natural history of infection and that of organised living ferments such as yeast, in respect of the almost infinite multiplication of an almost infinitesimal charge planted in a suitable soil under suitable conditions,

* To these four postulates, formulated by Koch, Martin has added a *fifth, namely,* that the secondary infective agent (toxin) separable from *the tissues in the* natural disease should have similar chemical and *physiological action* to the products obtained from a pure cultivation of *the microbe.*

and also in respect of the effect of reagents in checking or permanently arresting their increase.

The germ theory is now generally accepted, even in respect of those specific diseases, such as rabies, in which no characteristic microbe has yet been isolated. The chief alternative view which has been advocated is that infection is due to an un-organised chemical ferment, comparable to diastase, the microbes being regarded as (at most) effects or collateral phenomena, without causative influence as regards disease.

What the precise relation between the germs and the production of the varied phenomena of disease may be is less clear. Under certain conditions the enormous multiplication of the microbes may lead to obstruction of vessels—a "mechanical mycosis"—but the ordinary course of symptoms cannot be accounted for by any physical properties of such minute particles. They act mainly by modifying the physiological processes of the tissues—*e.g.* by depriving the red corpuscles of oxygen, or by forming some chemical product (or toxin), as a result of their growth and multiplication, which in its turn diffuses and acts as a poison.

Five principal hypotheses, in some degree overlapping each other, have been advanced to account for the protection conferred by an attack of such a disease:—

1. The *exhaustion* or *pabulum* theory is that the microbes during the first attack remove some chemical substance necessary for their growth, the loss of this substance rendering further attack impossible. This view involves the improbable assumption that the human body contains a special and separate pabulum suited to each specific disease to which it is liable, since one disease is only protective against itself.

2. The *antidote* or *retention* theory assumes that the first attack leaves in the system some direct or indirect *product* of the growth of the microbes which

inhibits any further multiplication. There is experimental evidence in support of this view, as will be seen presently, and sterilised or filtered cultivations of certain pathogenic microbes have been found (if injected into the system) to have a protective action, which, curiously enough, does not necessarily include any power of checking the growth of the specific microbes outside the living body, in artificial media. The effect therefore is not due to direct action on the microbes, but to increase of resistance.

3. According to the *acclimatisation* theory, the cells and tissues are in some way modified during an attack so as to be able to resist future invasions of the same microbe. The tissues, in short, have acquired a tolerance of the poison of a certain disease, and subsequently that infection does not produce the former symptoms of disease.

4. The *phagocyte theory*, somewhat allied to the theory of acclimatisation, is based on Metchnikoff's observation that when virulent anthrax bacilli are inoculated into an insusceptible animal (such as a frog), the white (amœboid) blood corpuscles absorb the bacilli bodily, and presumably destroy them. The same happens when attenuated virus is inoculated, even into susceptible animals; the bacilli may be seen partially or wholly embedded in the amœboid corpuscles. When a susceptible animal is inoculated with virulent anthrax, however, few if any bacilli can be seen inside the corpuscles. The inference to be drawn from Metchnikoff's observations is that the amœboid corpuscles act as "phagocytes," or destroyers of pathogenic microbes; and that "protection" is largely, if not entirely, dependent upon this action. The same hypotheses may serve to account for the termination of an attack. It may be assumed that all the pathogenic microbes perish or are eliminated at the end of an attack of most of the infectious diseases,

but pass into a quiescent stage in the intervals of malarial and relapsing fever. In tuberculosis, leprosy, and syphilis, their development may be progressive

5. *Ehrlich's side chain theory.* Ehrlich looks upon a molecule of normal protoplasm as composed of a central atom cell with a large number of "side-chains" of atom groups. The central cell is the mother cell, the side chains are *receptors*, that is, cells having combining affinity with food-stuffs by which nutriment is brought to the mother cell. These receptors are of two kinds, those having power of combining with molecules of simple constitution, and those having power of breaking up compound bodies by ferment action for the purposes of assimilation. Toxins are provisionally regarded as possessing two kinds of elements, *haptophorous* (*i.e.* the atomic group responsible for union with side chains of cells) and *toxophorous* (*i.e.* the toxic atomic group). When introduced or occurring in the system toxins are fixed to the receptors by the former, while the latter remain free, and if in sufficient number or quantity produce the toxic changes. If the dose of toxin is small the mother cell throws off the receptor plus the toxin (R + T), which thus becomes free in the blood. The central atom group then produces new receptors which in their turn are set free. Ultimately the toxin being exhausted there is over-regeneration of receptors and the excess of unfixed receptors become free in the blood, constituting antitoxin molecules. Thus, when forming part of the mother cell the receptors anchor the toxin, which sets up toxic effects, but when the receptors are free in the blood (R + T) we have an inert compound without toxic effect. This ingenious theory assumes that antitoxins are normally present in the body in varying degrees, but when stimulated by introduction of toxin become increased.

Bacteria and Disease.—The terms microbe, micro-organism, bacterium, germ, are applied almost indifferently to an increasing number of microscopic organisms which are destitute of chlorophyll and consist of protoplasm enclosed in a cellulose membrane. They multiply by fission, and are therefore termed *Schizomycetes*, or *fission fungi*. They may be classified, according to their form, their mode of reproduction, their effect on certain artificial media, their powers of motility, etc. The common basis of primary classification is, however, their morphology as—

Micrococci.—Minute spherical microbes, without cilia. They multiply by elongating and then dividing transversely, forming *diplococci* (*i.e.* pairs), *streptococci* (chains), *staphylococci* (clusters), *sarcinæ* (square groups of four cocci, or multiples of these), or *zooglœa* (irregular masses embedded in a gelatinous matrix).

Bacilli.—Rod-shaped, with rounded or square-cut ends; longer than they are broad. Some have flagella, others have not and are immotile. They elongate, and may form rods of any length, or divide transversely into separate short rods or chains of rods or zooglœa. Some bacilli form spores under certain conditions, among which may be mentioned moisture, suitable temperature, and presence of oxygen. The spores are round or oval glistening bodies, which appear in the substance of the bacillus, and grow at the expense of the protoplasm until the sheath bursts and liberates them. They are extremely resistant to heat and cold, but in certain artificial media spores readily germinate, a projection appearing at one point and growing into a bacillus.

Spirilla and *Vibriones.*—Long, wavy, and motile (ciliated) filaments. Some of these are non-septate, others are subdivided and may break into bacillary elements, as, for example, Koch's spirillum of cholera, which is known in a bacillary form as the comma bacillus of cholera.

The higher bacteria include more highly organised members of the Schizomycetes which branch and reproduce themselves by terminal fructification in conidia. To this group belong leptothrix, cladothrix, and streptothrix. The last named seems likely to become the most important member of the group from a pathogenic point of view. The exact

biology of these higher bacteria has not been finally worked out, and it is possible that further research may show that sometimes they are but forms in a life-history of an organism appearing at some stage in bacillary form.

Micrococci are of constant occurrence, and pathogenic in septic processes, acute suppuration, acute infective osteo-myelitis, and erysipelas. There is strong but not absolutely complete evidence to the same effect in respect of pneumonia, gonorrhœa, ulcerative endocarditis, scarlet fever, and puerperal fever; micrococci are generally present in active lymph of vaccine and small pox, and the virulence is largely or wholly lost when they are removed by filtration; but beyond this the proof of their being the actual *materies morbi* is incomplete. Ammoniacal fermentation of urine is determined by *M. ureæ*, which converts urea into ammonium carbonate. Certain diseases of animals, are believed to be due to specific micrococci. Micrococci are also concerned in decomposition.

Bacilli are known to be pathogenic in anthrax, tuberculosis, tetanus, glanders, and leprosy and are believed to be so in enteric fever, diphtheria, septicæmia, influenza, syphilis, and various forms of food intoxication. Many diseases affecting lower animals are due to specific bacilli, and among them malignant œdema, swine fever, and *Rauschbrand* ("symptomatic anthrax" or "black leg"). The fermentation of cheese and butter, and the souring of milk and cream are likewise due to certain bacilli. Each fermentation and most forms of decomposition possess a specific ferment of this nature.

Spirillum Obermeyeri is found in the blood during the acute stages of relapsing fever; the spirillum of cholera, or *Vibrio choleræ asiaticæ*, is now generally regarded as the cause of cholera; and other forms of spirillum occur in certain tropical diseases.

It should be mentioned that other micro-organisms,

not classed with bacteria, have relation to disease and fermentative processes. Thus thrush is due to *Oidium albicans*, a mycelial form of a torula (*Saccharomyces* [illegible]). Mycelial growths with spores or *conidia*, are associated with ringworm (*Trichophyton tonsurans*), favus (*Achorion schönleinii*) and pityriasis versicolor (*Microsporon furfur*).

Actinomycosis is characterised by the presence of a mycelial growth with masses of club-shaped corpuscles radiating from the centre—the *streptothrix actinomyces* or ray fungus. Somewhat similar organisms are the *streptothrix maduræ* occurring in Madura foot, and the pathogenic streptothrices recently described. These all belong, provisionally, to the higher bacteria. Minute amœboid bodies termed plasmodia by Laveran are pathogenic in malaria, and parasitic amœbæ, twelve times the size of white blood corpuscles, have been found in the intestines and fæces in cases of dysentery, and in pus from tropical abscesses of the liver associated with dysentery.

Organisms incapable of independent existence having their habitat in living hosts, animal or vegetable, are termed parasites, while those living upon dead organic material are known as saprophytes. Many microbes are capable of [illegible] though not necessarily with equal facility. Parasites that have not been found to grow under any known conditions as saprophytes are distinguished as "obligate," others as "facultative." [illegible] is an example of a facultative parasite, and the unknown microbes of [illegible] and many other infectious or inoculable diseases may be provisionally classed as obligate. Cultivation in artificial media, that is, a form of saprophytism, is essential for the complete proof of the pathogenic nature of a given microbe. Bacteria may therefore be classified as parasitic or otherwise, as pathogenic or other.

Other classifications may depend upon the characteristic growth of bacteria in artificial media in pure culture, and their effect upon such media, and whether they grow under aerobic or anaerobic conditions.

The action of microbes is essentially one of oxidation. As a rule carbonic acid gas is given off, but many known and unknown bodies are formed coincidently, which vary greatly with the pabulum as well as with the microbe. Among these are the poisonous alkaloids (toxins), which, so far as certain pathogenic microbes are concerned, are usually to be regarded as the immediate agents in the production of disease-symptoms. They are soluble, and even when freed from their respective microbes have in certain cases been found to be capable of producing a slight and transient appearance of characteristic symptoms. They may also be protective against disease, and it has been shown, for example, that the injection of filtered fluid in which anthrax bacilli have been cultivated protects against subsequent or even coincident inoculation with virulent anthrax. Hankin isolated from cultures of the anthrax bacillus an *albumose,* the injection of which into mice renders them insusceptible to anthrax. Brieger and Fränkel have isolated pathogenic albumoses from cultures of the specific microbes of diphtheria, enteric fever, cholera, and tetanus. Roux and Yersin believe the soluble poison to be a ferment, and Martin has shown that in anthrax and diphtheria the microbe produces such a ferment or *enzyme*, which reacts on the tissues to form *albumoses*, and that these break up into simpler bodies, which possess the specific toxic virulence and protective power.

Cultivation. Microbes derive oxygen either from the air or from compounds containing oxygen; in the former case they are termed *aërobic*, in the latter anaërobic. Ye[ast] (*Saccharomyces cerevisiæ*) is anaërobic, and acquires oxygen

the expense of the sugar, which is reduced to alcohol; the "vinegar plant," *Mycoderma aceti*, is aërobic, and oxidises alcohol into acetic acid. Aërobic microbes grow best at the surface of a liquid, anaërobic organisms deeper down away from contact with air or aërated layers of fluid. The distinction is not absolute, and many microbes are able to exist under either condition (*facultative anaërobes*).

Besides oxygen, microbes require nitrogen, which some are able to take from salts, such as ammonium tartrate, while others can only assimilate it from albumen or gelatin. Carbon is necessary, and also inorganic salts, including sodium, potassium, and phosphoric acid. Cultivation media should be neutral or faintly alkaline.

Both liquid and solid media are used. Among fluid media are broths made from various kinds of meat, peptones, meat extracts, hydrocele fluid, Pasteur's solution (water containing cane sugar, ammonium tartrate, and yeast-ash), and Cohn's solution (water with ammonium tartrate, potassium phosphate, tricalcic phosphate, and magnesium sulphate). Some of the more common solid media are boiled potato, solid egg-albumen, solid hydrocele fluid, blood serum, agar-agar, nutrient gelatin (gelatin with admixture of meat extract), etc. The medium must be adapted to the organism.

After thorough sterilisation by heat, media are kept in sterilised test-tubes, guarded, by means of sterilised plugs of cotton wool, against infection by air-borne germs. Each tube may then be "inoculated" by means of a previously sterilised platinum wire charged with the microbes to be cultivated; the wool plug is removed momentarily for this purpose, and then replaced. Potato cultures are made by inoculating the freshly cut surface of a boiled potato cut in strips and placed in sterilised test tubes. For plate-cultivation, a small portion of the liquid under examination is diffused through melted nutrient gelatin or other suitable medium, and then poured into a Petri plate (which is a flat, shallow glass dish), and allowed to solidify by cooling; protection from aërial germs is afforded by a glass cover. The temperature must be kept constantly at the point which experience has shown to be most favourable for the microbe in question. For this purpose an "incubator" is used, in which the temperature is regulated automatically. (Room temperature, or cool incubators, are regulated at 18 to 22° C., and blood heat incubators at 37 to 38° C. The temperature is regulated by thermo-regulators.)

Liquid media which solidify offer great advantages. If more than one variety of microbe is present, the resulting colonies tend to remain distinct, and it is comparatively easy

to establish a pure cultivation of each by inoculating afresh from it. Plate-cultivations are especially useful in this way, since by regulating the proportions the distribution of the colonies may be made as sparse as is necessary. Accidental contamination by aerial organisms is readily prevented. Another important advantage is that pure cultivations upon solid media frequently exhibit naked-eye peculiarities of outline and characters of growth that are important as means of identification. Another method of obtaining a pure cultivation is adopted by cultivating under conditions inhibitory to some microbes, but not to certain others: this is effected by adding phenol (*Parietti*), tauro-cholate of soda (*McConkey*), crystal violet (*Drigalski and Conradi*), etc., or by maintaining the temperature at 45° C.

Among the points that serve for the differentiation of the large number of varieties of bacteria are the following:—Microscopic appearances, as to form, size, structure, movement; effect of certain staining and decolorising agents; media in which growth occurs, and temperature required; rate of growth; macroscopic (and if necessary microscopic) appearance of cultivation in solid media, including form, colour, distribution (superficial or deep), liquefaction of gelatin, production of gas, etc.; results of inoculation upon animals.

Attenuation of virus has been effected in several ways.

1. *Subculturing from old cultures.*—Pasteur found that an organism retains its virulence unimpaired if kept in sealed tubes for a short time only, or is cultivated with a minimum interval between the successive cultures. If, however, the cultivation is allowed to remain for weeks or months without subculturing, the virus is attenuated, and when inoculated causes a mild but protective form of the disease.

2. *Cultivation at high temperatures.*—Pasteur prepared a "vaccine" (*i.e.* an attenuated virus) of anthrax by cultivating the bacilli for three weeks in air at 42° to 43° C. There is no visible chan

the mode of growth during this period except that spores are rarely if ever formed, but spore formation is immediately resumed if the bacilli are transferred to a fresh culture at ordinary temperatures. The virus becomes more and more attenuated if the temperature is maintained, and in about a month the bacilli all perish. The attenuation is brought about more rapidly at higher temperatures; a few days suffice at 45° C., a few hours at 47° C., a few minutes at 50° to 53° C. The original virulence is regained speedily upon transferring the attenuated bacilli to fresh media at ordinary temperatures, if the attenuation has been rapid. If, however, it has been slow, it is difficult to restore the virulence.

3. *Cultivation in presence of inhibitory reagents.*—Klein cultivated anthrax bacilli in gelatin containing 0·0025 per cent. of mercuric chloride, and obtained an attenuated virus which for a time protected guinea-pigs. Cultivations from the attenuated virus were virulent. Other reagents, including potassium bichromate, phenol, and terchloride of iodine, have been employed in like manner; or the organism may be grown on a medium which is either slightly too acid or too alkaline.

4. *Transmission through insusceptible animals.*—Anthrax bacilli from sheep or cattle cause fatal anthrax if again inoculated upon susceptible sheep or cattle, or upon white mice; but bacilli taken from white mice produce only a transient illness in sheep, which, however, is protective. Assuming Jenner's view to be correct, vaccinia is an example of attenuation of virus, that of small-pox being so modified by transmission through the (insusceptible) cow as to produce a mild but protective form of the disease.

It must not be forgotten that the opposite of *attenuation* may also be obtained. Exaltation of virus *results* from early sub-culture on favourable media

and the passage of the virus through susceptible animals.

These changes brought about in the laboratory by artificial means find a close parallel in the varying virulence of epidemic diseases. Sometimes the type, whether of small pox, scarlet fever, diphtheria, or measles, will be malignant and fatal, and at other times the same disease will be so mild as to cause scarcely any deaths.

Toxins and their effect.—When a pathogenic organism grows in the body, it produces as a result of its metabolism certain poisonous substances termed *toxins*. These may occur as a direct result of the life of the bacillus, or as a result of a ferment produced by the bacillus. Toxins are of various kinds, and by their effect upon the blood and body tissues they cause the symptoms of disease. Fever is produced by the action of albumoses (bodies allied to the albumins) upon the heat-regulating centres in the brain. Albumoses also cause a number of other symptoms and poisonous effects. Toxins act, broadly speaking, in two ways. They have a local effect (as in the formation of an abscess owing to necrosis of proliferating cells), and a general effect. The latter is caused when toxins are absorbed and distributed generally throughout the body. When this occurs they produce degenerative changes in muscles, in organs, and in the blood itself. Of such a change diphtheria is an example. The bacillus occurs in a false membrane in the throat, and occasionally other parts. It first causes the inflammatory condition giving rise to the membrane, and then it breaks it down. In the body of the membrane the bacillus appears to secrete a ferment which by its action and interaction with the body cells and proteids, chiefly those of the spleen, produces *albumoses* and an *organic acid* (*Martin*), which are the toxins. They are *absorbed*, and as a result we get the frequent pulse

and high temperature of fever: the toxins irritate the mucous membrane of the intestine, and cause various fermentative changes in the contents of the intestines, and thus we get symptoms of diarrhœa: they penetrate the liver, spleen, and kidney, setting up fatty degeneration and its results in these organs: they finally affect many of the motor and sensory nerves, breaking up their axis-cylinders, and producing the characteristic paralysis.

Toxins have been divided by Martin into *extra-cellular* (ferments, albumoses and alkaloids) and *intra-cellular*, or poisons present in the body of the bacillus and not "available" if the bodies of the bacilli be filtered out.

The virus of *anthrax* produces albumoses and an alkaloidal substance (*Martin*), the former producing fever, the latter œdema, congestion, and local irritation. Hankin holds that the bacillus first produces a ferment and then elaborates albumoses. In *tetanus* the bacillus produces a secretion of non-proteid toxin which causes convulsions. The albumoses present in this disease are probaby due to the secretory toxin. Ehrlich has isolated a spasm-producing toxin (*tetanospasmin*), and a crude poison capable of destroying red blood cells (*tetanolysin*). The nature of the tetanus toxin is not determined, but it is known that it is a most powerful poison, probably less than $\frac{1}{250}$ of a grain being poisonous to man. In *diphtheria*, too, we have a secretory poison in the membrane and in the tissues, and an albumose which is possibly the result of the secretion. In *typhoid fever* intra-cellular bacillary poisons exist, and a toxalbumin has been obtained which has pathogenic effects of an indefinite character. The toxins of the typhoid bacillus appear to have little *digestive* effect.

The action of bacteria as disease producers depends *then (1) upon* the effects of the presence of the bacteria

themselves, (2) upon their power of forming, directly or indirectly, certain chemical organic products known as *toxins*, and (3) upon the individual attacked. The effects of bacteria, though very diverse, may be classified generally as of a *necrotic* or a *separative* character, leading to increased functional activity at first (such as phagocytosis), and subsequently to increased formative activity (such as cell growth and subdivision). In most diseases the lesion has a special site (as in typhoid fever) and the body generally is only affected indirectly. This localisation may be due to specific action, or to point of entrance of the bacillus (as in malignant pustule). Secondarily to tissue changes, the body metabolism is affected owing to the absorption and distribution of toxins, and it is to this cause, as a rule, that the chief symptoms of disease are due. Finally much depends upon the soil upon which the bacteria and their toxins are implanted. The individual is an extremely important factor in the production and character of disease.

Antitoxins are believed by some authorities to be a kind of ultra-toxin, substances of which an early form was a toxin; others hold that, as the toxins are products of the bacteria invading the tissues, the antitoxins are of the nature of ferments produced by the resisting tissues. A third view is that possibly antitoxins may be the result of an increased formation of molecules normally present in the tissues. Thus antitoxins came to be looked upon as protective substances produced *in the body cells* as a result of toxic action, and held in solution in the blood, and there and elsewhere exerting their neutralising influence by combining with the toxins. These antitoxic bodies gradually increase in the blood and tissues, and their actions fall into two groups, (*a*) *antitoxic*, which counteract the effects of the poison itself; and (*b*) *antimicrobic*, which counteract the effects of the

bacillus itself. "In one and the same animal the blood may contain a substance or substances which are both antitoxic and antimicrobic, such, for example, as occurs in the process of the formation of the diphtheria and tetanus antitoxic serums" (*Martin*). Antitoxin must, therefore, be looked upon as a normal constituent of the living cells which is produced in increased quantity. Of the chemical nature of toxins and antitoxins, very little is known. Toxins are probably of the nature of albumoses, and antitoxins probably have a molecule of greater size, and may be allied to the globulins. Antitoxin has been shown to appear in the various secretions of the body as well as in the blood, though in a less concentrated state. The relation of the antitoxin to the toxin, and its mode of antagonism, is probably analogous to chemical union.

Immunity depends upon some property in the living blood serum which opposes or annuls, partly or wholly, the products and action of the infecting organism. Buchner designated these protective bodies, held in solution in the blood, *alexines*, and regarded them as belonging to the albuminous bodies of the lymph and plasma. Alexines are *naturally* produced antitoxins; ordinary antitoxins are *acquired* alexines, corresponding to "natural" and "acquired" immunity. The term *natural immunity* is used to denote natural resistance to some particular specific disease. It may be due to species of animal, or age, or individual idiosyncrasies. Examples of this freedom from disease are not infrequently met with. Certain species of animals do not, as a rule, take certain diseases. For example, cholera and typhus fever which affect man do not affect the lower animals. Swine plague does not affect man. The white rat is *immune to* anthrax, which readily attacks cattle. *Acquired immunity* is a protection not belonging

to the tissues of individuals naturally and as part of their constitution, but acquired during life in one, or both, of two ways. Either it may be an *involuntarily* acquired immunity, or a *voluntarily* acquired immunity—a natural attack of disease, or an artificial attack such as that due to inoculation. Small-pox, and a number of other diseases, rarely attack the same individual twice, because each of these diseases leaves behind it, so to speak, its antitoxic influence. Hence the individual has *involuntarily* acquired immunity against these diseases. An example of voluntary acquired immunity may be found in the old method of preventive inoculation for small-pox, or *variolation.* This was an inoculation setting up an artificial and mild attack of small-pox, by which the antitoxins of that disease were produced, protecting the individual against further infection of small-pox; that is to say, it was a voluntary acquired immunity. This form of artificial production of protection is *artificial immunity.* When artificial immunity is produced by direct inoculation of attenuated bacteria in toxins (as in vaccination or Pasteur's treatment of rabies) the condition is known as *active immunity;* where antitoxins are inoculated (as in the antitoxin treatment of diphtheria) the condition is that of *passive immunity.*

CHAPTER XIII.

DISINFECTION.

Disinfection is the destruction of the specific virus upon which infection depends, and *disinfectant* is equivalent to *bactericide.* It is, however, often loosely applied also to *antiseptics*, that is, to substances that arrest or impede the growth of microbes without destroying their vitality, and even to *deodorants* or reagents that destroy or mask the effluvia which are the frequent by-products of bacterial growth.

It is probable that protracted exposure to air and light will ultimately destroy most, if not all, pathogenic microbes, although under favourable conditions the virus of tuberculosis and other transmissible diseases has been known to retain its vitality for many years. It would seem also that mere diffusion in the atmosphere may render a virus inert. Typhus attacks a very large proportion of those who come into close contact with typhus patients, but rarely spreads under other conditions, even if the isolation is imperfect. Small-pox, on the other hand, is believed to be carried by air currents for long distances under favourable meteorological conditions. Spores of pathogenic bacilli would doubtless be among the most resistant, but mechanical portability (influenced by the form of the microbe and the size and weight of the epithelial scales or other particles to which it may be attached), the dryness (or the reverse) of the air, and the chemical effect of the atmospheric oxygen, are possible factors, and it is at all events conceivable that a certain minimum "dose" of the virus is

necessary for infection, so that mere dilution beyond a given point would render the virus harmless, even without destroying its vitality. According to Koch, mere drying (desiccation) kills the cholera bacillus.

The complete disappearance, often for long periods, of measles and other infectious diseases from a district after a widespread epidemic is in itself a sufficient proof that an enormous amount of *contagium* does in some way or other speedily become inert, apart from all attempts at disinfection and the exhaustion of available susceptible material.

Mechanical removal of infection from rooms or garments is often an important adjunct to disinfection proper. Walls are stripped of paper, or scraped, or rubbed with dough, or washed, floors are washed or swept; a strong current of air is sent through the room; garments are washed or brushed, or beaten, and hung out in the open air. As a rule, such measures, though effectual as far as they go, are in themselves incomplete safeguards, since some portion of the virus may escape dislodgment, and there is no certainty as to the future harmlessness of the rest.

True disinfection, that is destruction of germs, may be effected by heat or by chemical methods.

Disinfection by heat is the simplest and most thorough of all methods. With articles of small value, the safest plan is of course to burn them, but when this radical remedy is inapplicable, disinfection may usually be effected by exposure to moist or dry heat.

The experiments of Koch, Parsons, and others, have shown that bacteria and even spores of some bacilli are destroyed by exposure to steam at a temperature of 212° F. for five minutes, or to hot air at a temperature of 220° F. for four hours. Less resistant organisms, for example micrococci or bacilli free from spores, are destroyed by hot air at 220° F. in an hour.

Water at a temperature of 212° F.—that is, boiling water—is at least as efficacious as steam.

The mode of experiment was to steep threads in cultures of the respective organisms, and after exposing them to known temperatures for measured periods, to test their vitality by inoculation or further cultivation; "control experiments" were, of course, made in each instance, to prove that threads treated in exactly the same way, except as regards exposure to heat, gave positive results in cultivation or inoculation. Anthrax spores and anthrax bacilli serve admirably as test objects, since they are themselves pathogenic, and can be readily cultivated or inoculated, with characteristic and unmistakable results. Little is known with certainty as to the specific microbes of the ordinary infectious diseases attacking man, and in regard to them inoculation experiments are inadmissible, so that for the present we can only place reliance upon such processes as are found experimentally to destroy the most resistant of other organisms, namely, the spores of bacilli.

In practice the problem of disinfection is almost always complicated by the fact that the virus is not exposed freely, but enclosed in garments, pillows, or even beds; that is, in more or less bulky articles made of materials that have been selected for use as being the worst conductors of heat.* It is found

* Wool and silk are the warmest materials used for clothing. Not only are they bad conductors of heat, but they absorb a considerable amount of moisture without becoming damp. The watery vapour of perspiration is condensed, and its latent heat rendered sensible, while the tenacity with which the moisture is held prevents re-evaporation and chill. Linen and cotton are much better conductors of heat, and absorb little water. Perspiration readily makes them damp, and they are then chilly owing to evaporation.

A brief note may be introduced here respecting the microscopic and chemical characters of these materials. *Under the microscope*, wool fibres, *like hair, are straight*, unbranched, and exhibit faint cross-markings and *marginal indentations*, due to the imbrication of the scales. Silk filaments *have no such* markings, and are structureless except for occasional nodes. *Linen fibres have* many nodes, with ragged branching filaments. Cotton

that steam rapidly penetrates into the interior of such objects. The first portions condense, parting with their latent heat in so doing, and create a partial vacuum, so that successive supplies of steam follow continuously until a temperature of at least 212° Fahr. is attained at the centre. Dry hot air, on the contrary, being dependent upon conduction, very slightly aided by convection, has no such power, and it is practically impossible to raise the temperature at the centre of a bed or similar bulky object to 212° Fahr. by dry heat within any reasonable number of hours. Hot air moistened by steam is superior to dry hot air in penetration, but not in germicidal power, and is far inferior to steam in both respects.*

fibres are flat and twisted, without nodes or branches. The chemical reactions are shown in the following table :—

Reagent.	Wool	Silk.	Cotton	Linen
Potash or Soda (hot strong solution) .	Dissolves.	Dissolves	Nil.	Nil
Sulphuric Acid . .	Nil	Dissolves slowly	Gelatinises.	Gelatinises.
Nitric (or Picric) Acid . .	Turns yellow.	Turns yellow	Nil.	Nil.
Zinc Chloride (hot strong solution) .	Nil	Dissolves.		
Ammonium Cuprate (solution of CuO in NH_3) . . .	Swells.	Dissolves.	Dissolves.	Dissolves slowly.

* Under ordinary atmospheric pressure of 14·7 lbs. to the square inch, pure water boils at 212° F.; if the pressure be doubled, at 249°; if trebled, at 273°; these being the temperatures at which the vapour tension of steam is equal to the given pressure. Further heating of water beyond the boiling point at constant pressure (e.g. in the open air where the steam can escape freely) merely produces steam ("current steam"), the temperature of both water and steam remaining at the boiling point corresponding to that pressure. Steam thus in contact with water, whether under pressure or not, is "wet" or "saturated," and if cooled or if the pressure be increased it begins at once to condense to water again. If, however, it is further heated out of contact with water, it becomes "dry" or "superheated" and behaves as a permanent gas until such time as cooling or increase of pressure brings it to the condensing point.

Steam, in *condensing* to water, shrinks to $\frac{1}{1200}$ of its bulk, and *gives off latent* heat sufficient to raise its temperature 300° F. There is

Another important consideration is the effect upon the colour and texture of fabrics exposed to heat. Articles composed in part of fusible substances, such as glue or sealing-wax, are, of course, ruined by heat in any form. Steam is inadmissible for leather objects, since it shrivels them up and renders them worthless; hot air merely makes them temporarily dry and brittle. With these exceptions, steam is less injurious than hot air in almost all respects. New woollen goods, such as blankets and flannels, lose some of their whiteness and fleeciness by either process, but not more than in one or two ordinary washings. Silk and cotton are not injured by steam, nor by hot air if the temperature is carefully regulated. Dyes are surprisingly little affected by either steam or hot air.

The chief difficulty in steam apparatus is to prevent loss of heat, and condensation. This is overcome by surrounding the steam chamber with a "steam-jacket," that is, by making the wall of the apparatus double, and admitting steam into the space between the inner and outer casings. A door is provided at each end, one for the reception of infected goods, and the other for removal of the goods after disinfection. The doors are steam-tight, and are fastened by strong screw-clamps. The articles to be disinfected are placed in trays, or suspended from sliding racks.

Washington Lyon's apparatus is oval in section, and is usually worked with a pressure of 10 lbs. per square inch in the jacket and 5 lbs. in the chamber, so that the steam in the latter is superheated, a further precaution against condensation. The articles having been introduced, and the doors closed and secured, steam is first sent into the jacket so as to heat the contents of the chamber. Steam is next admitted into the chamber itself, and soon reaches the full pressure required. It is found that penetration is more rapid if the pressure is intermitted once or twice, which is readily effected by turning a

corresponding expansion and absorption of latent heat in conversion of *boiling water into* steam. At any given pressure the boiling point of *water containing* salts in solution is slightly raised.

cock. Ten to twenty minutes suffice for the penetration of even bulky objects, and at the end of that time the steam is allowed to escape from the chamber, the door is opened, and the articles are removed. Further drying may be effected if necessary by leaving the door ajar for a few minutes, and exposing the articles to heat from the jacket.

In Goddard, Massey, and Warner's apparatus the lower part of the jacket serves as the boiler, and the pressure in the chamber is the same as that in the jacket, usually about 20 lbs., so that the steam is not superheated. After the articles are put in and the door closed, hot air is drawn through for two or three minutes, and this is repeated after the ten or twenty minutes' exposure to steam.

The Equifex disinfector, upon the model of Geneste and Herscher, largely used on the Continent, has no steam jacket, but is lagged, and hot steam-pipes within the chamber serve to lessen condensation and dry the disinfected articles. The usual pressure is about 10 lbs., and the steam is not superheated.

Low-pressure steam—that is, steam under pressure only slightly, if at all, exceeding the atmospheric pressure—was found by Koch to be not inferior in germicidal power to steam, at higher pressure. Van Overbeek de Meyer devised an apparatus in which the steam, generated at atmospheric pressure in a jacket-boiler surrounding the chamber, passed in through an opening at the top. The temperature did not exceed 212°, but the results were practically as good as those attainable with high pressure. In Thresh's Current Steam Disinfector a somewhat higher temperature is obtained without pressure, by the use of a saline solution, in place of plain water in the jacket-boiler. Reck's is still simpler, the jacket being dispensed with.

All of these fulfil the essential conditions—namely, rapidity of penetration, destruction of all organic life in the interior of bundles of moderate bulk without injury to fabrics, and lastly, convenience in working. High pressure, intermitted, has perhaps some advantage in rapidity of disinfection of exceptionally bulky articles; but for ordinary purposes the simpler and less costly low pressure apparatus is almost equally good. Esmarch has cast doubt upon the germicidal efficiency of superheated steam.

Hot-air-disinfection apparatus labours under a threefold disadvantage as compared with steam. The available temperature and duration of exposure are limited by the tendency to scorch the articles exposed; the penetration of heat is so slow that it is practically impossible thoroughly to disinfect objects of moderate thickness, such as pillows; and lastly, the germicidal effect of a given temperature is far less with hot air than with steam. The only advantage that can be claimed for hot air is that leather and bound books are not spoiled by it as they are by steam.

The best apparatus of this kind is that devised many years ago by Ransom. It consists of a rectangular chamber of wood and iron, lined with non-conducting material. Hot air mixed with the products of combustion passes into the chamber after being heated by a number of gas jets; the temperature of the hot blast is kept constant by an automatic mercurial regulator, which controls the gas supply and can be set for any required temperature. An outlet with a chimney is provided at the top of the chamber. The best working temperature is about 255° F., this being the highest that can be used for long periods without danger of singeing cotton goods. Thermometers are placed at the inlet and outlet. If the contents of the stove should take fire owing to overheating or to lucifer matches being left in the pockets, the gas is automatically turned off and the entrance of air arrested, by the falling of a weighted lever, which, until such accident occurs, is held suspended by a chain attached to a fusible metal bar in the interior of the chamber. It is customary to expose articles to hot air at about 255° F. for two, four, or eight hours or more, according to their bulk, but for reasons already stated the penetration of heat is very limited.

The following figures, which give the mean values obtained in a series of 120 experiments, serve to show how slowly the temperature rises in the interior of woollen objects exposed to hot air. Registering *maximum* thermometers were placed beneath layers *of blanket.* The inlet temperature was about 255°

F. throughout the series, and the final outlet temperature 245° to 250° F. :—

Duration of Exposure.	2 layers.	4 layers.	6 layers.	12 layers.	18 layers.
4 hours . .	220° F.	208° F.	190° F.	162° F.	130° F
6 „ . . .	226° „	214° „	208° „	174° „	153° „
8 „ . . .	230° „	221° „	215° „	196 „	182° „

In striking contrast to the above were the results of another series of experiments with steam apparatus, the same blankets being employed. An electric thermometer, ringing at 212° F., was placed beneath sixteen or more layers of blanket, and served to indicate the exact interval between the first exposure to steam and reaching 212° F. Different forms of steam apparatus were tested, with low pressure as well as high, and the maximum interval noted was 17 minutes.

It is essential that any apparatus for disinfection by heat should have doors at opposite ends, opening into entirely separate rooms provided with separate entrances. One of these rooms should be strictly reserved for infected and the other for disinfected goods, and no articles should on any account be allowed to enter the latter room except through the stove, the object being of course to guard against the danger of reinfection of the purified articles.

Chemical disinfection has been shown by the accurate experiments of Koch and others to be a matter of considerable difficulty, and comparatively few of the so-called disinfectants in common use prove to be really germicidal under the conditions of actual practice. A convenient but severe test is to expose to the "disinfectant," for a definite period, threads which have been soaked in a cultivation containing *anthrax spores* and then dried. After the "disin-

fection," cultivation or inoculation experiments show whether the spores survive or not, control experiments being made at the same time. Among the very few substances which killed the spores within a day (and for practical disinfection this is far more than can often be allowed) were mercuric chloride (1 per cent.), carbolic acid and potassium permanganate (5 per cent.), and chlorine and bromine water. A 4 per cent. solution of carbolic acid took three days, and 1 per cent. permanganate had no effect in two days. Among those which failed were 5 per cent. solutions of chloride of lime, zinc salts, copper sulphate, ferrous sulphate, boracic acid, and sulphurous acid, and ·5 per cent. carbolic oil. Several of these, however, are able to kill less resistant forms, such as sporeless anthrax bacilli; or, serving as antiseptics, to prevent multiplication. A substance, to be a satisfactory disinfectant, should possess five characters: (*a*) it should be germicidal within a reasonable time limit; (*b*) it should not possess chemical properties which unfit it for ordinary use; (*c*) it should be soluble in water, or capable of giving rise to soluble products in contact with the material to be disinfected; (*d*) it should not produce injurious effects on the human tissues; and (*e*) it should not be too costly in proportion to its germicidal value. The substances which fulfil all these requirements are not numerous. Many valueless experiments have been made respecting such chemical bodies, because the conditions necessary to valid and comparable results have been ignored. These conditions are chiefly three, namely, using disinfectants which give regular and consistent results, using standardised bacterial cultures as to age and source, and working with the same organism. Out of the confusion of contradictory findings it is possible, however, to name a number of reliable disinfectants. *The liquid* reagents most in use are mercuric chloride

(1 to 500), potassium permanganate (5 per cent.), formalin (40 per cent. solution), carbolic acid (5 per cent.), zinc chloride (2·5 per cent.), chloride of lime (1 to 2 per cent.), creosol, cyllin, lysol, creolin, and many compounds of the aromatic series (*e.g.* izal and Jeyes' fluid, which contain the higher phenols, and form emulsions with water).

A most important consideration in regard to the more potent reagents forming the first series is their "working strength." If, for example, it is proposed to disinfect a putrescent liquid by means of permanganate of potash, it is absolutely useless to add a little of a 5 per cent. solution of the salt. We must add either the solid permanganate or a highly concentrated solution, until the permanganate is present as such to the extent of 5 per cent. of the whole weight of liquid, this 5 per cent. being of course in addition to the amount required to oxidise the organic matter. These essential conditions are rarely if ever observed in practice, and "disinfection" by permanganate consists really of deodorisation with partial oxidation of organic matter. A similar consideration applies to mercuric chloride, which, if added to liquids containing organic matter, forms a precipitate that carries down part of the mercury in an inert form, and if sulphuretted hydrogen is present, the equally inert sulphide of mercury is thrown down. So, too, with carbolic acid, which must form not less than 5 per cent. of the whole weight of liquid—not merely of the stock solution—if it is to destroy anthrax spores.

Mercuric chloride is one of the chief reagents that can be conveniently employed in solution under such conditions as to destroy the most resistant microbes. One part of mercuric chloride in 1,000 of water destroys anthrax spores, according to Koch, but other observers have found this strength inadequate. The great drawback to this reagent is its extremely poisonous nature, but it may be kept in fluted poison bottles properly labelled, and the solution may be artificially coloured with indigo, and "odorised" with thymol, as further safeguards. The following proportions are suggested in a memorandum of the

L.G.B.:—$\frac{1}{2}$ oz. mercuric chloride, 1 oz. hydrochloric acid, and 5 grains of commercial aniline blue, in three gallons of water. This ought not to cost more than one penny per gallon and should not be further diluted. Non-metallic vessels (wooden or earthenware) should be used. Articles soaked in the mercurial solution should be steeped in water for some hours before washing. Whether the contagia of human diseases are amenable to less potent reagents is still an open question, but for the present it is not safe to assume this.

Many fluid disinfectants are now applied direct to infected surfaces by means of a sprayer (Equifex, Mackenzie, etc.), such as chloride of lime (1 to 2 per cent.), carbolic acid (5 per cent.), formalin (40 per cent. solution, 4 ozs. to the gallon).

Fumigation.—For the disinfection of rooms and other closed spaces the principal reagents in use are sulphurous acid, chlorine, bromine, nitrous acid, and formic aldehyde. Sulphurous acid is usually generated by setting fire to fragments of roll sulphur in an iron vessel, with the addition of a little spirit to facilitate lighting. Sulphur candles are convenient substitutes, or bisulphide of carbon may be burnt in a lamp. The prescribed proportions are 1 to 3 lbs. of sulphur to every 1,000 cubic feet of air space, yielding theoretically 1·1 to 3·3 per cent. of sulphurous acid in the air of the room.

Chlorine is most conveniently produced by adding crude hydrochloric acid to chloride of lime. The strength of the latter varies, but as a rule $1\frac{1}{2}$ to 2 pints of the acid should be allowed for each pound of chloride of lime. No heat is required; indeed the reaction is so rapid that it is necessary to secure time for the operator to escape, by letting the acid drip through a small hole upon a little cup which, when full, overflows into the dish containing the lime. The

quantities required, according to German experiments, are very large—about 15 lbs. of chloride of lime and 22 lbs. of hydrochloric acid * for every 1,000 cubic feet. These quantities, being somewhat prohibitive, are commonly reduced to one-tenth or less in practice. The reagents should be divided into a convenient number of portions and placed in several parts of the room in positions as near the ceiling as practicable.

Nitrous fumes are generated by adding copper filings or other reducing agents to nitric acid.

In any case the room must be rendered as nearly air-tight as possible before fumigation. Paper should be pasted over the fireplaces and ventilators, and around the window-sashes and doors, leaving, of course, one door to be pasted up on the outside after the operator quits the room. It is desirable to render the air of the room moist by means of steam or water before fumigating by sulphurous acid or chlorine, to an extent sufficient to moisten the walls and other surfaces.

In ordinary rooms it appears that the unavoidable leakage is considerable, so that the theoretical proportion of the gas is only present for a very short time, if at all. The slightest protection shields even sensitive microbes from the action of the fumigant; very few are killed which lie in crevices, or in the pocket of a coat, or are wrapped in filter paper. Koch's experiments in an almost air tight box showed that sulphurous acid, in the proportion of 1·0 per cent. of the cubic space, killed anthrax bacilli and other sensitive organisms in half an hour, but that anthrax spores and other spores of bacilli resisted 6·0 per cent. for days. The addition of moisture greatly accelerated the action upon bacilli, and so far increased the effect upon spores of bacilli

* Strong sulphuric acid may be substituted for crude hydrochloric acid. About a third of the quantity would suffice.

that some of them were killed by exposure to 5 per cent. sulphurous acid for twenty-four hours.

Formic aldehyde vapour can be obtained by various devices in the way of lamps (paraform lamp burning 30 tabloids per 1,000 cubic feet); more effectively by Trillat's autoclave, a somewhat costly apparatus, in which its 40 per cent. aqueous solution, known as formalin, is treated at high pressure in presence of calcium chloride, the gas being passed through the key-hole by means of a tube; or by Lingner's apparatus, in which glyco-formal (formalin 30 per cent. and glycerine 10 per cent.) is vaporised and ejected as a fine spray. If the formalin is simply heated much of the aldehyde changes into a solid polymeride *paraform.* The amount of formalin required for each thousand cubic feet of air-space in a room is variously stated as 150 to 500 c.c. The vapour, in the proportion of 1 per cent. in air, or solution of 0·5 per cent. strength, is found to destroy most organisms. For purposes of fumigation formic aldehyde has advantages over sulphurous acid and chlorine in its lower density, which gives it greater diffusibility and some power of penetration, and in its more rapid action. It acts best if the air is dry, and is harmless to most colours and most surfaces except iron. The vapour is irritating, but readily cleared away by ventilation.

Klein, Houston, and Gordon, in 1902, found that formic aldehyde gas (30 tabloids of ·034 oz. each to 1,000 cubic feet space) killed the cholera and typhoid bacilli, and the diphtheria bacillus, as well as *staphylococcus pyogenes aureus,* in five hours, and devitalised tubercular sputum on linen and paper. The same may be said of sulphurous acid gas (3 lbs. to 1,000 cubic feet) in 24 hours, except that the sputum remained unaffected. Anthrax spores were not killed uniformly under any of these conditions.

It would seem, therefore, that if precautions are

taken to reduce the leakage to a minimum, fumigation by sulphurous acid, chlorine, or formic aldehyde, may be able to destroy most, if not all, of those microbes that are not very resistant, and that happen to be freely exposed upon the surface.

Fumigation is to be regarded as—at most—a disinfection of air and of surface. Even this is an important step in the direction of safety, for the surface is precisely that portion of an infected article which is most readily and most largely charged with infective matter, and from which, moreover, infection is most readily given off to persons handling or coming into contact with the *fomites.* As a preliminary process it affords some degree of security to those engaged in carrying out later and more thorough measures of disinfection. It can be supplemented, as regards surfaces, by washing with soap and water, or with a disinfectant solution; wall-papers can be stripped off, or lime-wash renewed.

Disinfection of the air of a room is practically ensured by the free ventilation which in any case must be effected, but if infected surfaces or articles are allowed to remain, the air may at any time again become charged with infective matter accidentally dislodged from its resting-place.

Besides the germicidal power of the reagent there are three other conditions essential to disinfection—namely, sufficient strength or intensity, maintained for a sufficient time, with sufficient contact or exposure.

In few departments of hygiene have absurd generalisations been so prevalent as in reference to disinfection. "Disinfectants," or substances labelled as such, are still widely employed under conditions which a moment's reflection would show to be utterly incompatible with any real efficacy. Passing over such trivialities as "fumigation" by burning brown paper or green sticks, we have the wholesale employment of deodorants and antiseptics under the name of

disinfection, unsupported by any scientific evidence of their utility. The few true disinfectants in general use are commonly employed under such conditions as to quantity, concentration, and duration of exposure, that little benefit can result from them. Earth is popularly believed to be a universal disinfectant, and yet earth abounds in microbes, some of which are pathogenic. Indeed, the very nitrification upon which the purifying action of earth is so largely dependent is in great part due to the life and growth of microbes. It is often asserted that the danger of infection by diseased meat is exaggerated, because the process of cooking must destroy any microbes that may be present. Even as regards microbes, the temperature in the interior of joints obviously may fall far short of that required for disinfection, and the ptomaines and unorganised ferments (toxins) are in all probability uninjured by ordinary cooking. The gastric juice also is credited with a disinfecting power much greater than the evidence warrants. The "comma" bacillus and many others are destroyed by it, but spores may escape. Sarcinæ and other microbes may be found in abundance in the stomach itself, fully exposed to the alleged germicidal gastric juice; and in the intestine millions of microbes are always present. Moreover, it is now established beyond dispute that tuberculosis and other diseases are communicable to animals by means of the alimentary canal.

Attempts are often made to "disinfect" sewers and drains by flushing them with solutions of chloride of lime, carbolic acid, or ferrous sulphate. A little consideration will render it clear that any real disinfection of this kind is wholly impracticable, even if true disinfectants such as strong solutions of mercuric chloride are used. The reagent is quickly diluted by the contents of the drain, and rapidly passes away without coming even momentarily into effectual contact with the whole of the material and surfaces it is supposed to disinfect. If the drain or sewer is properly constructed, thorough flushing by water will be more effectual than the use of disinfectants.

Antiseptics are reagents which prevent, arrest, or impede the growth and multiplication of microbes, without necessarily destroying them. All true chemical disinfectants are still antiseptic when diluted, provided that the dilution is not carried too far (mercuric chloride has some trace of antiseptic power even at the enormous dilution of 1 in 300,000). Among

other important antiseptics are :—Boracic acid, borax, sulphurous acid; essential oils, including those of mustard, thyme, turpentine, peppermint, cloves, and eucalyptus; quinine and other alkaloids.

Antiseptics are employed mainly to prevent or arrest decomposition of organic substances. Apart from surgical purposes, they are used for the preservation of food, to prevent or restrain decomposition in organic refuse, as a precaution against rotting of timber, and in many other ways.

Deodorants serve to remove or mask effluvia. Among aërial deodorants, nitrous acid is one of the most powerful. Chlorine and the fumes given off by moist chloride of lime are also potent, and act by oxidation of organic matter; they decompose sulphuretted hydrogen, which is an important constituent of the gases of putrefaction. Hydrochloric acid fumes, like chlorine, neutralise the free ammonia and ammonium carbonate. Sulphurous acid may, perhaps, act in some degree as a reducing agent, and also as an antiseptic, but its chief effect is to overpower the effluvia and necessitate free ventilation. Fumes of wood, tar, or paper are quite useless except for the same reason.

Of the solid or liquid deodorants, ferrous sulphate and cupric sulphate act mainly by removing the sulphuretted hydrogen as a precipitate; potassium permanganate simply oxidises; carbolic acid and the essential oils exert an antiseptic effect and so check further decomposition, while at the same time their powerful odour masks all others. The ozone or peroxide of hydrogen which is believed to be associated with the essential oils may effect some small amount of oxidation.

CHAPTER XIV.

SPECIFIC DISEASES.

Small-pox has been described more or less clearly in Eastern countries for nearly two thousand years, and more definitely in Europe since the sixth century. No part of the world is exempt from epidemic visitation; but in India and the Soudan it is so constantly prevalent that these may be regarded as endemic foci. Pandemic extension occurs from time to time, characterised by the enormous areas attacked, and by the malignant type of the disease. The last of these was that of 1871-2, which overran Europe and America, and caused in England alone 42,000 deaths during the two years.

The whole epidemic character of small-pox has completely changed since the introduction of vaccination. The "bills of mortality" show that upon the average 7 to 9 per cent. of the persons buried in London during the seventeenth and eighteenth centuries had died of small-pox, and in epidemic years the proportion often rose to 13, 15, or even 18 per cent. The only approach to this state of things since the introduction of vaccination was in the pandemic year 1871, when 9·8 per cent. of the deaths in London were due to small-pox. The general mortality upon which this percentage is calculated is, of course, far smaller in proportion to population than in the last century. During the greater part of last century small-pox became somewhat prevalent in London every four or five years, but in the decade 1891-1900 it remained at a very low ebb, although there have been signs of reviving activity since 1900. The same remarks apply more or less to the other English

towns, all of which suffered heavily in 1871-2, and have with few exceptions been unprecedentedly free from the disease for the last few years. A severe epidemic occurred in Sheffield in 1887-8, however, in the manufacturing districts of Yorkshire and Lancashire, and at Gloucester in 1896, and throughout the country in 1902-3.

Season.—The mortality curve for small-pox in England is above the mean from January to June, and below it from July to December. The New York curve does not differ essentially from this, but rises to a more definite maximum in May. In India the maximum occurs in the cold season, namely, in March or April.

Soil is not found to have any influence upon the prevalence of small-pox.

Air.—In 1884-5 it was found by Power that cases of small-pox in the surrounding districts followed the admission of acute cases into Fulham Hospital. He showed that, if the district were divided into zones, by means of circles drawn upon the map from the hospital as a centre, with radii of $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, and 1 mile respectively, and an enumeration made of all the houses in each belt, and also of all houses invaded by small-pox, the proportion of invaded houses diminished as the distance from the hospital increased, and this relation held good in each "quadrant" of each zone (Fig. 23). Within the quarter-mile zone there was only one approach to the hospital, and this was in the N.W. quadrant. The distribution of cases in the several quadrants was not such as to suggest any relation to lines of traffic or ambulance routes. Power concluded that diffusion only occurred when *acute* cases were aggregated, and perhaps only under certain atmospheric conditions that cannot as yet be defined.

Barry found a similar radiation of infection from

hospital upon a larger scale in the Sheffield epidemic of 1887-8, but the possibility of personal convection could not be entirely excluded. Similar observations with similar results, namely, a graduated intensity of small-pox incidence as distance between small-pox hospital and a populous neighbourhood became less,

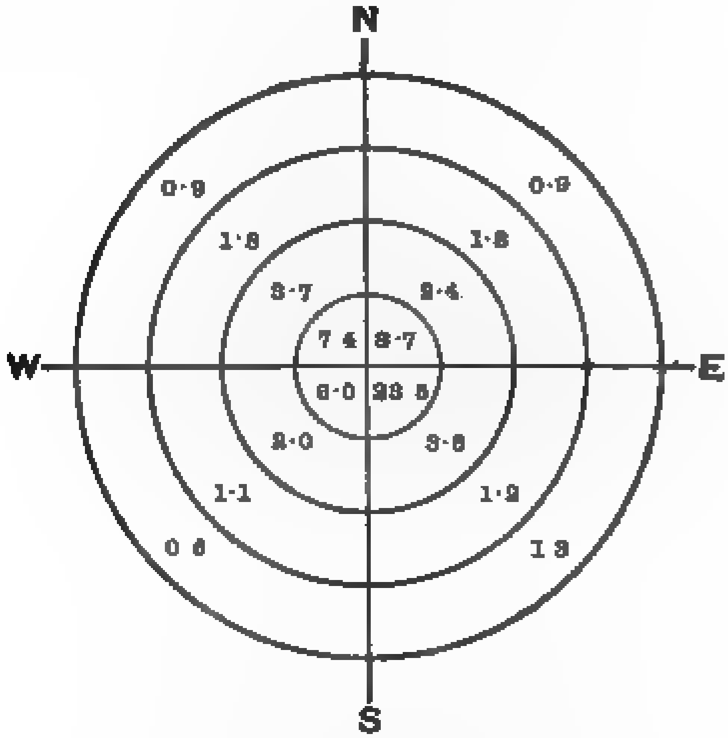

Fig. 23.—Incidence of Small-pox upon District around Fulham Hospital, May 25th, 1884, to September 26th, 1885.
The figures show the percentage of houses invaded in each quadrant and quarter-mile zone.

have been made at Oldham in 1893; Warrington 1892-3; Bradford 1893; Glasgow 1900-01, and the Orsett Union, adjoining the site of the small-pox hospital ships in the Thames, from 1884 to 1902. These and other careful investigations leave little room for doubt that under favourable conditions small-pox can be conveyed through the air, and for considerable distances. An observation at Nottingham, 1887-8, tends to show that

the same radiation may occur upon a small scale from a single acute case. The town had been absolutely free from small-pox for a year, when a case was imported and concealed in a crowded house in a dense quarter. On the south side this house was closely adjoined by courts and alleys that were only accessible (from the north) by a long and circuitous route; streets and houses on all the other sides of the house in question were freely accessible. Three houses situated in the isolated courts on the south were invaded, but none in the directions in which traffic could pass. The dates of attack in each case corresponded with the hypothesis of aërial convection from the concealed case during the acute stage, and the wind was northerly at the time of probable infection in each. Confirmatory evidence as to such diffusion of small-pox from centres outwards has been repeatedly recorded.

Neither water nor milk has been shown to convey the infection of small-pox.

Age and sex.—The mortality from small-pox is greater among males, not only at all ages taken together, but also, with few exceptions, at each age period. The exceptions are the second and third year of life, and the tenth to the fifteenth year, at all of which, from some unexplained cause, the female mortality slightly exceeds the male.

The relation to age has to be considered with reference to vaccination In pre-vaccination times, as McVail has shown from the Kilmarnock registers, 90 per cent. of the deaths were at ages below five years, the actual maximum being in the second year. Under present conditions, the deaths under five years, being practically limited to unvaccinated children, constitute only 30 per cent. of the total small-pox deaths, and in this age period the greatest mortality *occurs in the first* year, being, indeed, highest in the

first three months of life. It diminishes steadily from this point until about the fifteenth year, rises to a second maximum about the twenty-fifth year, and thenceforward diminishes again.

Race.—Coloured races, and especially negroes, have a peculiar susceptibility to small-pox. They take it more readily, and suffer a heavier case mortality, than white races, apart from all question of vaccination.

The *incubation period* is usually twelve days, or counting to the appearance of the rash, fourteen days, so that the rash is seen on the fifteenth day, on the same day of the week that the infection was acquired. There are, however, exceptions to this rule. Inoculation of small-pox is followed by constitutional symptoms on the seventh or eighth day, and the general rash appears on the tenth or eleventh. Even after infection by more ordinary means it is stated that the latent period may range from seven to eighteen days; and the rash is often delayed until the fourth day (*i.e.* the third *after* onset) instead of appearing on the third.

Infection is given off, presumably by the breath, from the earliest onset. The exhalations, the vesicles, pustules, and scabs are also highly infectious. The virus may be carried by air currents, as already mentioned. It readily lodges in clothing, and retains its vitality tenaciously; hence outbreaks are liable to occur in paper-works and other manufactures in which rags are employed. Isolation should be maintained for at least three weeks in the mildest case, and always until every scab has disappeared—a process which, in confluent cases, will take six weeks, and often considerably longer. After exposure to infection, a quarantine of seventeen days—to allow a margin over the fortnight—is sufficient. Second attacks are rare, except after several years' interval. Third attacks are not unknown.

Diagnosis.—The medical officer of health is not unfrequently consulted as to the diagnosis of variola, and it may be desirable therefore to add here the main points to be borne in mind as characteristic of the disease:

Sudden attacks of fever, headache, vomiting, backache (most marked in the lumbar and sacral regions) generally begin from 12 to 14 days after infection. Rigors are often present. Vomiting and retching are sometimes severe. In children (and even in adults occasionally) these initial symptoms may be obscured by drowsiness.

These initial symptoms last two or three days before the characteristic rash appears. But in some cases accompanying these symptoms are various forms of mild eruptions, which may simulate measles or scarlatina. Such eruptions are frequently localised to different parts of the body.

The characteristic eruption of small pox appears about two days after the onset of the backache, fever, etc. It consists at first of a number of small red pimples or spots, which gradually enlarge and become hard and "shotty" to the touch. After they have been out for about 48 hours they begin to become small bladders or vesicles, containing at first clear, and, later on, purulent matter (pustules). They are about the size of a split pea, are surrounded by a thin red zone (or areola), are definitely raised above the level of the skin, often assume the colour of dull pearl, and in many cases show a central depression (umbilication). About the eighth or ninth day the pustules begin to dry up, so that from the first appearance of the rash, the successive stages of pimple, vesicle, and pustule occupy about ten or eleven days. Simultaneously with its appearance on the skin, the eruption appears on the mucous membrane of the mouth and palate.

In persons who have been vaccinated the rash is somewhat modified (varioloid) and comes out more rapidly, the vesicles are smaller and less abundant, not so much depressed in the centre, and may not become pustular.

An important point is *the distribution of the rash.* The first spots generally come out on the face, particularly on the forehead and around the lips. Almost immediately afterwards they appear on the limbs, being particularly marked on the wrists and ankles. Afterwards the rash appears on the back, whilst the skin on the front of the chest is less affected and the skin of the abdomen least. A further point is that, as a rule, when the rash comes out the temperature falls and the patient feels better. In rare instances the rash is almost entirely suppressed, and *therefore* in times of epidemic the appearance of *the premonitory symptoms* alone should arouse suspicion

The three most important aids to correct diagnosis are—the premonitory symptoms, the character of the rash, and the distribution of the rash.

The precautionary measures to be taken in case of an outbreak of small-pox include immediate and rigid *isolation*, which can only be satisfactorily carried out in hospital, especially when the danger of aërial spread of infection is considered; thorough *disinfection; vaccination*, or *re-vaccination* of all persons who have been exposed to risk of infection, however remotely, those only being excepted who have recently (say within four years) undergone successful vaccination, or who bear marks of recent small-pox. No reliance can be placed upon verbal assurances as to previous attacks, or even as to vaccination, and after a time the protection of previous small-pox, as well as of vaccination, may vanish.

The pathogenic microbe of small-pox and vaccinia may possibly be a bacillus (*Klein* and *Copeman*). It is found most readily in early lymph, about the fifth day, and can be cutivated upon the hen's egg, though not upon ordinary media.

Inoculation of small-pox (*variolation*), already referred to above, was generally practised in England in the eighteenth century, having been introduced from the East in 1721 by Lady Mary Wortley Montagu. It seems to have been customary to inoculate from the primary vesicle, not from the secondary rash. Mild cases were selected, and the lymph was taken before suppuration set in. The fatality (2 or 3 per cent.), though far lower than that of "natural" small-pox, was by no means trifling, and the readiness with which the risk was incurred is a strong illustration of the magnitude of the danger to which it was the only known alternative. It was superseded by vaccination, and was finally forbidden by law in 1840.

Vaccination, introduced by Jenner in 1796, gradually superseded inoculation during the earlier part of the last century. It was provided gratuitously by the first Vaccination Act of 1840, made compulsory in

1854, and systematically enforced by paid vaccination officers from the time of the pandemic in 1871. Under the Act of 1898 more latitude has been allowed to the conscientious objector.

DEATH-RATES FROM SMALL-POX, PER 1,000 LIVING AT EACH AGE-PERIOD.*

	All Ages	0–5.	5–10	10–15.	15–25.	25–45.	Over 45
1847–1853. Vaccination gratuitous but optional . .	0·305	1·617	0·337	0·094	0·100	0·066	0·022
1854–1871. Vaccination compulsory but not efficiently enforced .	0·223	0·817	0·248	0·088	0·168	0·131	0·052
1872–1891. Vaccination enforced .	0·089	0·177	0·095	0·054	0·097	0·086	0·038

This table shows that each extension of vaccination was attended with a reduction in the small pox mortality, in which, however, the different ages by no means shared equally. The reduction was greatest at the ages of highest mortality -that is, among children under 10 years of age while at ages over 15 the change was comparatively slight. In the third period the latter no longer included, as in former generations, a large proportion protected by non-fatal attacks of small-pox undergone in early life, and on the other hand the protection due to infantile vaccination had had time to fade. Moreover, even unvaccinated persons had, under the new conditions, a better chance of

* Reg.-Gen. 43rd Ann. Rep.; and Foster, British Medical Journal, i., *1898, p. 1069.* The ages were not abstracted before 1847.

escaping small-pox until adult life. The enormous reduction in mortality among young children whose vaccination was recent speaks for itself, and it must not be forgotten that the mortality at ages under 5 years occurs among the unvaccinated residuum, the vaccinated being practically exempt, as will be seen presently.

Another illustration of the great change in the age-incidence of small-pox has already been given. At Kilmarnock, from 1728 to 1764, there were 622 deaths from small-pox, of which 563, or 90 per cent., were at ages below 5 years. The corresponding proportion in England from 1871 to 1880 was 30 per cent. Buchanan* gave other instances in the following table, with an analysis of the age-incidence of small-pox mortality in London in 1884 upon the vaccinated and unvaccinated, *separately*, from which it is manifest that the old conditions remained unchanged among the unvaccinated, except that the protection which the rest of the community had acquired lessened the probability of exposure to infection :—

CONTRIBUTION OF VARIOUS AGES TO 100 SMALL-POX DEATHS AT ALL AGES.

	Geneva, 1580–1760	Kilmarnock, 1728–1764.	Paris, 1842–51.	London, 1848–51	London, 1884.		
					Unvaccinated.	Vaccinated.	Whole Community.
0–10 years	96·1	98·8	39·[illegible]	81·5	61·2	8·[illegible]	34·3
10–20 "	2·6	0·5	13·3	[illegible]·9	14·6	17·4	17·0
20–30 "	1·0	0·7	32·[illegible]	8·3	10·8	31·9	21·3
30–40 "	0·3	—	11·0	3·2	7·2	22·1	14·2
Over 40 "		—	3·1	1·1	6·2	20·1	13·2
	100·0	100·0	100·0	100·0	100·0	100·0	100·0

* *Report of the Medical Officer to the L.G.B. for 1884.*

An analysis of the returns of the 5,683 small-pox deaths in London during the ten years 1879-88, as given by the Registrar-General, yields the following results :—

AGES.	Of 1,406 stated to be *Vaccinated.*	Of 2,265 stated to be *Unvaccinated.*	Of 2,012 Vaccination not stated.	Of the total 5,683, irrespective of Vaccination.
	Per cent.	Per cent.	Per cent.	Per cent.
0 to 10 years ..	8·4	56·0	35·0	36·8
10 to 20 years ..	16·0	17·2	14·7	16·0
Over 20 years	75·6	26·8	50·3	47·2

Confirmatory evidence, if any be needed, is afforded by Barry in reference to the Sheffield epidemic of 1887-8 :—

SHEFFIELD, 1887-8.—SMALL-POX ATTACKS AND DEATHS (PER 1,000 PERSONS OF EACH CLASS STATED).

	Attack-rate		Death-rate.	
	Vaccinated.	Unvaccinated.	Vaccinated.	Unvaccinated.
0-10 years	5	101	0·1	44
Ditto, living in invaded houses	78	869	1	381
Over 10 years	19	94	1	51
Ditto living in invaded houses	281	686	14	371
All ages	15·5	97	0·7	48
Ditto, living in invaded houses	280	750	11	372

From these statistics it appears that the vaccinated part of the population had, as compared with the unvaccinated, *at ages below* 10 *years*, a 20-fold immunity from attack, and 480-fold security against death from small-pox ; *at ages above* 10 *years*, a 5-fold immunity from attack, and 51-fold security against death from

small-pox; *at "all ages,"* a 6-fold immunity from attack, and a 64-fold security against death from small-pox.

Sheffield Hospitals, 1887-8. *Proportion of mild ("varioloid" and "discrete") and severe ("coherent" and "confluent") cases per* 100 *attacks among persons of each class stated.* (BARRY.)

	Vaccinated.		Unvaccinated.	
	Mild.	Severe.	Mild.	Severe.
0–10 years	91·0	9·0	21·8	78·2
All ages	82·8	17·2	18·5	81·5

As regards London, the proportion of small-pox deaths to deaths from all causes is available as a measure of the prevalence of the disease before and after the introduction of vaccination, which came gradually into operation at the beginning of the 19th century. From the "bills of mortality" it appears that during the thirty-one years 1770-1800 small-pox caused 59,253 out of the 626,530 deaths in London, or 9·4 per cent. In the thirty-one years 1801-31 the proportion was 4·6 per cent. From 1832 to 1837 no returns are obtainable; but for the thirty-one years 1838 to 1868

Period before Vaccination.	Period after Vaccination.	Locality.	Mean Annual Small-Pox Mortality per 1,000.	
			Before Vaccination.	After Vaccination.
1777-1806	1807-1850	Lower Austria	2·48	0·34
1777-1806	1807-1850	Upper Austria and Salzburg	1·42	0·50
1781-1805	1810-1850	Berlin	3·44	0·18
1774-1801	1810-1850	Sweden	2·05	0·16
1751-1800	1801-1850	Copenhagen	3·13	0·29

the proportion was 1·4 per cent. Even in 1871, when the pandemic wave reached London, the deaths from small-pox were only 9·8 per cent. of the total deaths, a proportion very little in excess of the *average* which prevailed between 1770 and 1800.

The figures in the table at the foot of page 338 are quoted from Seaton.

The greater susceptibility of the unvaccinated to the small-pox virus is manifested not only in a greater liability to attack, but in a higher case mortality.

The quality of vaccination also—that is, the number, area, and character of the cicatrices—has an important bearing upon the degree and permanence of the protection afforded. Both of these points come out clearly in all large hospital statistics, of which the following two examples will suffice:—

Case Mortality in relation to quality of vaccination and to age, based upon an analysis of 10,403 cases in Metropolitan Small-Pox Hospitals. (GAYTON.)

Ages.	Vaccinated. Good Marks.			Vaccinated. Imperfect Marks.			Said to be Vaccinated. No Marks.			Unvaccinated.		
	Cases.	Deaths.	Case Mortality.	Cases.	Deaths.	Case Mortality.	Cases.	Deaths.	Case Mortality.	Cases.	Deaths.	Case Mortality.
0-5	51	0	0·0	182	21	11·5	128	47	36·7	677	383	56·6
0-10	267	2	0·7	714	48	6·7	825	87	20·8	1,187	563	47·4
10-20	1,045	17	1·6	1,976	98	5·0	419	81	19·5	521	160	30·7
20-40	725	37	5·1	1,898	258	13·6	420	140	33·3	382	181	47·4
Over 40	48	6	12·5	266	51	19·2	131	44	33·6	79	34	43·0
All ages	2,085	62	3	4,854	455	9	1,295	352	27	2,169	938	49

Case Mortality in relation to number of vaccine cicatrices. (MARSON.)

	Case Mortality (per cent.)
Unvaccinated	35½
Stated to be vaccinated, but without cicatrices	21¾
Having one cicatrix	7¾
Having two cicatrices	4⅛
Having three cicatrices	1¾
Having four or more cicatrices	¾

Re-vaccination renews in all respects the immunity given by primary vaccination. As regards entire populations, the results of general, if not universal, re-vaccination are shown in the following figures, taken from the report of the German Vaccination Commission of 1884. After the pandemic of 1870-74, re-vaccination was made compulsory in Germany *only*, and small-pox has never become seriously epidemic during the years that have since elapsed; while in other countries the incidence continued much as in the period before 1870.

SMALL-POX DEATH RATES.

	Austria.	Prussia.*	Berlin.*	Hamburg.*	London.	Paris.	Vienna.
1870	0·30	0·175	0·22	0·25	0·30	5·46	0·46
1871	0·39	2·432	6·32	10·75	2·42	?	0·74
1872	1·90	2·624	1·38	0·95	0·53	0·06	5·36
1873	3·23	0·337	0·11	0·008	0·04	0·01	2·28
1874	1·78	0·095	0·024	0·005	0·02	0·02	1·35
1875	0·58	*0·036*	*0·051*	*0·000*	0·01	0·13	1·13
1876	0·39	*0·031*	*0·018*	*0.018*	0·20	0·20	1·67
1877	0·53	*0·003*	*0·004*	*0·012*	0·70	0·07	0·84
1878	0·61	*0·007*	*0·007*	*0·002*	0·38	0·04	0·75
1879	0·51	*0·013*	*0·007*	*0·000*	0·12	0·45	0·46
1880	0·64	*0·026*	*0·008*	*0·000*	0·12	1·09	0·73
1881	0·83	*0·036*	*0·047*	*0·022*	0·61	0·49	1·23

The German Vaccination Law was passed in 1874 compelling vaccination and re-vaccination. Infants must be vaccinated before the end of the calendar year following the year of birth, and *all* children must be re-vaccinated in their twelfth year. Obedience to this law is enforced by fine or imprisonment. So completely is this system worked, that there is less need for the strict isolation of small-pox than in England. For instance, in Germany, the rare cases

* *Italic figures* are inserted for the years in which compulsory re-vaccination was in force.

of small-pox are placed in pavilions of general hospitals, not in separate small-pox hospitals. The population of Germany is 56 millions, and from 1891 to 1902 inclusive, there were 607 deaths recorded as due to small pox. The small-pox deaths during the same period in England and Wales (population 32 millions) were 6,761. If the ratio had been the same in England as in Germany, there would have been only 350 deaths.

Barry shows that in the Sheffield epidemic the re-vaccinated had a great advantage over the rest. Of 8,198 persons re-vaccinated prior to the epidemic, 25 were attacked and 1 died, the attack-rate being therefore 3·0 per 1,000, and the death-rate 0·1. Among 56,233 persons re-vaccinated during 1887-8, 2 were doubtfully attacked and none died.

It may be convenient to summarise the evidence as follows:—

A. *As regards vaccinated and unvaccinated populations respectively.* (1) In pre-vaccination times the heaviest incidence of small-pox was upon childhood. (2) In the unvaccinated part of the community it is so still. (3) Among vaccinated persons childhood is exempt, and small-pox is only fatal in later years, when the protective influence of vaccination has faded. (4) In a mixed community (vaccinated and unvaccinated) both these effects are apparent, the heavier incidence upon the unvaccinated compensating for their scanty numbers. (5) The immunity at early ages among the vaccinated may be extended indefinitely by re-vaccination. (6) In every epidemic, in every community, and in every year—if the numbers are sufficiently large to preclude fallacy—the unvaccinated suffer more attacks *in proportion to their numbers* than the vaccinated, and (7) a larger percentage of the attacks are fatal. (8) Among the vaccinated who suffer from small-pox in later years, the proportion of fatal to non-fatal attacks diminishes as the number or area of the cicatrices increases.

B. *As regards entire populations.* (9) The introduction of vaccination has in all cases been followed by a lowered average incidence of small-pox. (10) Each extension of compulsory vaccination *has led to a further reduction.* (11) Compulsory *re-vaccination* has almost entirely suppressed small-pox.

The vaccine virus is that of cow-pox or vaccinia, a disease formerly prevalent among cattle, but now rarely met with. It occurs in the form of vesicles upon the teats and udder in cows. The virus is inoculable upon human beings as well as cows, and this inoculation constitutes vaccination. Goats also are susceptible. No person is insusceptible except as the result of previous vaccination, or an attack of small-pox.

Primary vaccination in the human subject is followed on the third day by a papule, which on the fifth or sixth day is vesicular. On the eighth day the vesicle is mature; it is greyish, elevated, tense, loculated, and contains a clear viscid lymph which exudes when the vesicle is pricked. On the ninth day inflammatory changes set in; the lymph begins to contain pus, and a reddish "areola" surrounds the vesicle. Slight constitutional symptoms are common at this stage. The vesicle becomes a pustule, begins to dry up about the tenth day, and forms a dark scab about the fourteenth. The scab falls off in the fourth week, leaving a permanent scar which should be depressed and pitted.

Vaccination may be carried on from arm to arm for an indefinite and probably unlimited number of years without having recourse to the cow again. The lymph should always be taken on the eighth day (that is, exactly a week after the vaccination) from normal and unbroken vesicles. No lymph should be collected after a re-vaccination, or from an unhealthy subject, or from vesicles showing any sign of inflammatory action. By far the surest plan is to vaccinate directly from the vesicle, but the lymph may be sealed in capillary tubes or dried upon ivory points, and retains much of its efficacy for a considerable time.

Vaccination by calf lymph is now in use upon a *large scale*, owing partly to a popular suspicion that *the current* arm-to-arm vaccination is losing its

power, but chiefly to the fear of the virus of syphilis or other malady being inoculated with the lymph from diseased human subjects. There appears to be no difference either in the course of the symptoms or in results between ordinary arm-to-arm vaccination and vaccination from the calf.

Vaccination is protective against itself as well as against small-pox. Any number of "insertions" may be made at the time of vaccination. Whether one vesicle is produced or a dozen, the protection is absolute for the time being, but all experience goes to show that the duration of the protection is limited, and is directly proportionate to the number and area of cicatrices produced. Hence it is desirable to vaccinate in at least four places, and the total area of the cicatrices should not be less than half a square inch. The return of the Metropolitan Asylums Board for the small-pox epidemic in London, 1901-2, respecting this point, is given here, and a study of it will amply prove the claim made.

		Admissions.	Deaths.	Mortality per cent.
Vaccinated cases—				
Area of Cicatrices	Half square inch and upwards	5,163	379	7·34
	One third but less than half square inch	835	131	15·69
	Less than one third square inch	960	162	16·87
	Not recorded	87	33	37·93
Totals of Vaccinated Class		6,945	705	10·15
Unknown and Doubtful Class		496	171	34·22
Unvaccinated Class		2,277	752	33·03
Grand Totals		9,658	1,628	16·87

As the protective influence of the primary vaccination fades, a time arrives when re-vaccination

becomes possible. Comparatively few persons are insusceptible to re-vaccination after the lapse of ten or twelve years; many "take" readily within five years, although the primary cicatrices may be good. The course of re-vaccination in the majority of persons is different from that of the primary operation, being more rapid, and often failing to exhibit some of the typical stages. If, however, the former protection has entirely disappeared, the course of re-vaccination may be identical with that of a primary vaccination.

Vaccine lymph contains, among other microbes, bacilli which Copeman regards as pathogenic. He finds, too, that it is possible to kill out the extraneous organisms by suitable admixture with glycerine, leaving the lymph still active. Filtration renders it inert. The virus is somewhat readily destroyed by chemical disinfectants, but the lymph can be kept in the dry state, or in sealed tubes, for months or even years, although it begins to lose some of its activity from the very first.*

Jenner believed that vaccinia was small-pox modified by transmission through the cow, a form of attenuation very similar to that which we now know to be possible as regards many other diseases. Cow-pox, formerly common, has become rare among cattle coincidently with the reduction in human small-pox due to vaccination. The seat of the eruption was the teats and udders of cows, a limitation that suggests contact with the hands of milkers as a means of inoculation. It is

* Glycerinated calf lymph is now prepared as follows:—A calf, aged three to six months, is kept in quarantine for a week. If then found upon examination to be quite healthy, it is removed to the vaccinating station, the lower part of its abdomen antiseptically cleaned. The animal is now vaccinated upon this sterilised area with glycerinated calf lymph. After five days the part is again thoroughly washed, and the contents of the vesicles, which have of course appeared in the interval, are removed with a sterilised sharp spoon, and transferred to a sterilised bottle. This is now removed to the laboratory, and the exact weight of the material ascertained. A calf thus vaccinated will yield from 18 to 24 grams of vaccine material. This is now thoroughly triturated and mixed with six times its weight of a sterilised solution of 50 per cent. chemically pure glycerine in distilled water. The resulting emulsion is aseptically stored in sealed tubes in a cool place. At intervals during four weeks it is carefully examined bacteriologically until by agar plates it is demonstrably free from extraneous organisms, when it is ready for distribution.

difficult to inoculate cows with small-pox virus, but if effected, vaccinia seems to result. Hime has done so, in the calf. Ceely succeeded twice in a large number of experiments, Badcock in only seven per cent. of his attempts, and other experimenters have failed entirely. Voigt claims to have succeeded by the device of vaccinating a calf in one part of its body, and at the same time inoculating with small-pox in another, true vaccine vesicles appearing in both places. Chauveau failed to produce vaccinia by inoculating calves with small-pox, but papules appeared at the points of insertion, and the contents of those papules inoculated upon susceptible human subjects gave rise, not to vaccinia but to small pox It is possible that Chauveau's results correspond to Ceely's and Badcock's failure, not to their few successes, since they, too, sometimes obtained slight local effects which they did not regard as vaccinia; and the reproduction of human small-pox by inoculation from the papules may have been due simply to the unaltered small-pox virus which he had inserted.

Bouley, and also Ceely, having produced such papules by inoculating small-pox matter, afterwards inoculated the same animals with vaccine matter, and with success.

The incubation of vaccinia being shorter than that of small-pox, it is possible to modify or even entirely prevent an attack of small-pox by vaccination performed some days after infection. This is especially the case with re-vaccination, the incubation of which is often shorter than in primary vaccination.

Successful vaccination within three days after exposure to infection will prevent the appearance of symptoms, and it is probable that the attack will either be arrested or modified by vaccination as late as the fifth or even sixth day. The proof of this rests upon the observation that attacks of small pox may, and do, occur within six days of vaccination in persons who have been many days previously exposed to infection, but the few attacks that occur between six and nine days after *successful* vaccination are mild, and practically none commence later. The usual incubation of small pox, it will be remembered, is twelve days.

The Royal Commission on Vaccination, 1896,

concluded that the protection vaccination affords against small-pox may be stated as follows:—

"(1) That it diminishes the liability to be attacked by the disease. (2) That it modifies the character of the disease and renders it less fatal and of a less severe type. (3) That the protection it affords against attacks of the disease is greatest during the years immediately succeeding the operation of vaccination. It is impossible to fix with precision the length of this period of highest protection. Though not in all cases the same, if a period is to be fixed, it might, we think, fairly be said to cover in general *a period of nine or ten years.* (4) That after the lapse of the period of highest protective potency, the efficacy of vaccination to protect against attack rapidly diminishes, but that it is still considerable in the next quinquennium, and possibly never altogether ceases. (5) That its power to modify the character of the disease is also greatest in the period in which its power to protect from attack is greatest, but that its power thus to modify the disease does not diminish as rapidly as its protective influence against attacks, and its efficacy during the later periods of life to modify the disease is still very considerable. (6) That revaccination restores the protection which lapse of time has diminished, but the evidence shows that this protection again diminishes, and that to ensure the highest degree of protection which vaccination can give the operation should be at intervals repeated. (7) That the beneficial effects of vaccination are most experienced by those in whose case it has been most thorough. We think it may be fairly concluded that where the vaccine matter is inserted in three or four places it is more effectual than when introduced into one or two places only, and *that if* the vaccination marks are of an area of half a *square* inch they indicate a better state of protection *than if* their area be at all considerably below this."

The **Vaccination Acts** of 1867, 1871, and 1874 have been modified by that of 1898. In general, a child must be vaccinated within six months of birth. The parent is relieved from obligation if within four months after the child is born he satisfies a magistrate that he conscientiously believes that vaccination would be prejudicial to its health, and within seven days thereafter gives the magistrate's certificate to the vaccination officer. And even in the absence of such an exemption, an order under the 1867 Act directing that a child be vaccinated cannot be made upon any person who has previously been convicted of non-compliance with a similar order relating to the same child. It is the duty of the public vaccinator, if the parent so requires, to attend the child at its home. If a child is not vaccinated within four months of its birth, the public vaccinator is to visit the home, after giving at least twenty-four hours' notice, and offer to vaccinate with glycerinated calf-lymph or such other lymph as the **L.G.B.** may provide. In either case, if he finds that owing to the condition of the house, or recent prevalence of infectious disease in the district, the operation cannot safely be performed, he is not to vaccinate, but must give a certificate of postponement, and inform the **M.O.H.***

Public vaccinators are to use only glycerinated calf lymph, or other lymph supplied by the **L.G.B.**, and must keep registers from which the origin of the lymph used in each operation can be identified. The

* The **L.G.B.** direct that, "except so far as any immediate danger of small pox may require, the public vaccinator must vaccinate only subjects who are in good health. As regards infants, he must ascertain that there is not any febrile state, nor any irritation of the bowels, nor any unhealthy state of the skin, especially no chafing or eczema behind the ears or in the groin, or elsewhere in folds of skin. He must not, except of necessity, vaccinate in cases where there has been recent exposure to the *infection of diseases* such as measles, scarlatina, or diphtheria, nor where *erysipelas is prevailing* in or about the place of residence."

Instructions require the greatest care as to cleanliness and sterilisation of instruments used, and aseptic precautions at all stages. "The public vaccinator must aim at producing four separate good-sized vesicles or groups of vesicles, not less than half an inch from one another. The total area of vesiculation resulting from the vaccination should not be less than half a square inch."

The **L.G.B.** may, in the event of serious risk of outbreak of small-pox or other exceptional circumstances, require the Guardians to provide vaccination stations, and may temporarily and locally modify the obligation upon the public vaccinator to visit otherwise than by request. Any **S.A.** maintaining a hospital for small-pox must keep a register of patients, showing name, age, address, and condition as to vaccination. The entries are to be made at the time of admission, and the register is to be accessible to the public.

A child must be vaccinated within six months of its birth unless (*a*) the parent obtains a magistrate's certificate of exemption, or (*b*) the child dies, or (*c*) is attacked by small-pox within that period, or (*d*) three or more unsuccessful attempts at vaccination have been made,* or a medical certificate of postponement (for not more than two months at a time) is given on the ground of ill-health, or of recent prevalence of infectious disease in the district, or of the condition of the house in which the child resides. Certificates of successful vaccination, or attack of small-pox, or of insusceptibility to vaccination, or postponement of vaccination, can be given by any registered practitioner.

Re-vaccination is entirely optional, but persons over twelve years of age are re-vaccinated gratuitously

* *In this event* insusceptibility is inferred; but out of 88,000 primary *vaccinations Cory* failed in only one instance, and in that one he had no *opportunity* of making a third attempt.

by the public vaccinator, and if there is immediate danger of small pox, the age limit is reduced to ten years.

The administration of the Vaccination Acts, subject to the control of the **L.G.B.**, is entrusted to the Poor Law Guardians, not to the **S.A.** Instructions and blank forms of certificate are issued by the sub-registrars to the parents at the time of registration of birth.

Varicella or chicken-pox was only clearly distinguished from small-pox in the last century, but beyond a certain superficial resemblance there is nothing in common between the two diseases. Varicella occurs as an epidemic, which not unfrequently coincides with small-pox outbreaks, and adds to the difficulty of diagnosis of mild cases of the latter. Persons of all ages are liable to attack, but children more than adults. The mortality is practically *nil*, a fatal result being unknown except in cases almost moribund from other causes, or in cases of *varicella gangrenosa*. Nothing is known of the conditions that determine the appearance of this rare and malignant type of varicella in individual cases during an outbreak of ordinary character.

The latent interval is very commonly a fortnight. The characteristic vesicular eruption, which may be very profuse and widely distributed, is thickest upon the back and shoulders. The vesicles are not usually umbilicated, although this is not a reliable point for diagnostic purposes, and among them are some that are aptly compared to drops of scalding water upon the skin, there being no induration around them. At other times varicella spots simulate small-pox more closely, but there is almost always a want of uniformity in size, appearance, and stage of development. The premonitory symptoms (vomiting, backache, anorexia, etc.) that accompany the onset of small-pox only, the distribution and appearance of the rash, the relation to vaccination, and the history of exposure to one or other kind of infection will seldom fail to make the diagnosis clear.

The infection of varicella is active from the first onset, and is readily imparted by contact or by means of fomites. The mode in which it is given off is unknown, but the breath is the most probable. Attempts have been made to inoculate from the vesicle, but without success. Second attacks are rare.

A quarantine of eighteen days is sufficient after exposure to

infection; after an attack, isolation should be kept up until all scabs have disappeared. In times of small-pox epidemic the L.G.B. or the county council or S.A. may make chicken-pox temporarily notifiable in order thereby to bring to light cases of small-pox simulating varicella.

Measles became clearly differentiated from small-pox and scarlet-fever in the seventeenth century. No country or race appears to be exempt from it, and it has no demonstrated relation to climate. Some dependence upon meteorological conditions may be inferred from the fact that the colder months, even in the tropics, are favourable to the rise and spread of measles epidemics. In London the seasonal curve of mortality shows two maxima, a principal one in December and a lesser one in June, the minima occurring in February and September.* The influence of age as regards liability to attack has not been worked out, but the mortality from measles is greatest in the second year of life, and rapidly falls in every succeeding year. Sixty per cent. of the deaths occur during the first two years of age, 75 per cent. in the first three, and upwards of 90 per cent. under five years. The mortality is greater among females at all ages above five years, but greater among males up to that point, so that upon the whole the female mortality is lower than the male.

Measles epidemics are occasionally so malignant in type as to have a case mortality of 30 per cent. or more, but in such instances neglect, improper treatment, or insanitary conditions have been largely responsible for the result. The epidemics now met with in Great Britain, though variable in severity of type, cause a case mortality that rarely exceeds five per cent., and is often not more than one or two per cent.

* The winter maximum vanishes in many parts of Great Britain and the Continent, particularly where the measles mortality is low, leaving a simple curve with a maximum in June and a minimum in September or October. (*Reg. Gen. Ann. Rept.* for 1884. See also "Measles Epidemics, Major and Minor," *Transactions of the Epidemiological Society*, 1892-3.)

The fatal cases are as a rule due to pulmonary complications or diarrhœa rather than to the primary disease itself, the tendency to the one or the other complication being often fairly constant throughout an epidemic, but apparently independent of season (*Hirsch*). Unlike scarlet fever, measles often disappears almost entirely from a district in the interval between epidemics. These intervals, however, are usually short, and few towns in England escape an epidemic for much longer than two or at most three years at a time. Insular communities such as Iceland and Faroe, with little communication with the outside world, remain free for an indefinite number of years after the subsidence of an epidemic, until infection is introduced afresh. Occasionally measles, like small-pox, becomes "pandemic" and diffuses itself for a brief period over a large part of the globe.

Measles is said to have been inoculated by nasal mucus (*Bristowe*) with an incubation of seven or eight days. It has no known relation to soil. It does not appear to be transmitted by drinking water, milk, or other food, or to have any connection with diseases of lower animals. "Insanitary conditions"—notably overcrowding, exposure, and want of food—diminish greatly the chance of recovery, as was found in the outbreak among French troops in the siege of Paris, when 86 out of 215 died. Whether such conditions increase the liability to attack cannot be stated. The virus appears to be readily conveyed by the air, probably for considerable distances, but of this exact proof is wanting. Measles has not yet been isolated upon the large scale, so that the question of the possibility of aërial spread of infection from hospitals has not arisen.

From analogy it may be assumed that a specific measles microbe exists, but none has yet been satisfactorily demonstrated.

Infection is probably always acquired by inhalation. The incubation period is usually about twelve days, and is followed by the stage of invasion marked by pyrexia and catarrhal symptoms affecting chiefly the respiratory tract and the conjunctiva. The rash appears on the fourth day of illness, first on the forehead, then becoming general. It consists of dusky pink, slightly elevated spots, which increase for two or three days, and then slowly fade. Slight scurfy desquamation follows. Infection is given off by the breath and mucus from the onset of the first symptoms, and very possibly even during the stage of incubation. It is not clear how long this liability continues, nor whether the desquamated cuticle is infectious, but the usual rule is to allow a quarantine of not less than three weeks. An attack is usually protective throughout life, and this is probably the main reason for the comparative immunity of adults, but well-authenticated instances of repeated attacks in the same person are far from infrequent.

Comparing measles with scarlet-fever, it is at once apparent that preventive measures are less likely to be successful against the former. Infection begins at least three days before the characteristic rash appears, and hence isolation is not adopted at a sufficiently early date to prevent the spread of the disease, so far as the household is concerned. The long incubation adds to the difficulty of quarantine.

Measles is still allowed to run its epidemic course practically unchecked by any serious attempt at isolation or disinfection, and it is, therefore, not surprising to find that it shows no signs of sharing in the reduction of mortality which is so conspicuous in respect of scarlet-fever, enteric fever, and small-pox. It is customary to close schools during measles epidemics, and there is, doubtless, great advantage in doing so in rural districts.

Whooping cough, or pertussis, has been recognised in Europe for 300 years, and has practically a world-wide distribution, although it appears to be on the whole less prevalent and less severe in hot countries. In London its average prevalence is greatest in March and April, least in September and October, but the seasonal curve of mortality varies greatly in different parts of Europe, and the New York curve has a second and greater maximum in September.

By far the greatest mortality occurs in the first year of life. Of the whole number of deaths from pertussis, over 40 per cent. occur in the first year, nearly 75 per cent. under two years of age, and 96 per cent. under five years. At every age the mortality among females is greater than among males. There are no statistics sufficient to show the actual or relative incidence of attacks at different ages, but the vast majority occur in children, although age confers no complete exemption. Concurrent epidemics of measles and whooping cough are frequent. Like measles, whooping cough is a typically epidemic disease, and recurs at short but irregular intervals (usually two or three years) in outbreaks that affect a very large proportion of susceptible persons. The case mortality is usually small, and probably seldom exceeds 5 per cent. The deaths are almost always due to bronchitis, pneumonia, convulsions, or other complications. Measles and whooping cough together are, as a rule, responsible for more deaths of children than all the other infectious diseases put together.

Whooping cough has not been shown to be transmissible by water, milk, or other food, or to affect lower animals, or to have any relation with telluric conditions. It is readily conveyed by fomites. Faulty hygienic conditions — especially overcrowding and *exposure*—*increase* the danger to life, but there is no

proof that they increase susceptibility. The specific microbe has not been isolated, nor is the disease known to be inoculable.

Whooping cough is, in all probability, always acquired by inhalation of the virus. The incubation period appears to be about a fortnight, but can rarely be fixed definitely owing to the very gradual onset of characteristic symptoms. Squire believed it to be less than a week. After a week or more of apparently ordinary nasal and bronchial catarrh, the characteristic paroxysmal cough sets in, and continues for a very variable period, which is rarely less than two weeks and may exceed two months.

Whooping cough is certainly infectious in the preliminary catarrhal stage, and possibly even earlier than this. Isolation ought to be maintained until at least a week after the spasmodic cough has entirely disappeared. The infection is given off in the breath and sputa. Second attacks are very rare.

What has been said as to the prevention of measles applies in all respects to whooping cough, and with even greater force. Owing to the absence of rash, and the insidious onset of symptoms, the disease is rarely detected until many days after it has reached the infectious stage.

Mumps (parotitis) occurs in all parts of the world in brief but often intense epidemics which cause little or no mortality. Cold and wet weather is the most favourable, and outbreaks usually occur in the winter and spring, often in concurrence with epidemics of measles, or sometimes scarlet-fever. Mumps usually disappears entirely from a district at the end of the outbreak, and there is no appearance of periodicity in its return, which may be delayed for many years.

Nothing is known of its etiology beyond its extreme infectiousness by means of the breath. Second attacks are very rare. The characteristic symptoms, including swelling of the parotid and sub-maxillary glands, set in after an incubation of about three weeks (often 19 days), and the disease runs its course in about a fortnight more. Three weeks is sufficient for

isolation, and four weeks for the quarantine of a person who has been exposed to infection.

Rötheln, epidemic roseola, or German measles, occasionally becomes epidemic among children, but causes very slight mortality. An outbreak in the New Forest in 1880 was, however, said to have been attended with a case mortality of 3 per cent. After a latent period, often about $2\frac{1}{2}$ weeks in length, slight general symptoms manifest themselves and are followed immediately, or in a day or two, by an eruption of red, slightly elevated spots, variable in size and often confluent. They appear first on the face and fore-arms, increase and become more or less general in one or two days, and disappear before the end of a week. The symptoms have some resemblance to those of scarlet-fever and measles, especially the latter. It is, however, an entirely distinct and independent disease, and not a "hybrid," as is popularly supposed. The disease is infectious, but never very actively so, and isolation for a fortnight is sufficient. Infection is probably given off by the breath, and acquired by inhalation. Second attacks do not appear to be common. Quarantine should extend to 23 days.

Scarlet-fever, or scarlatina, has been recognised in Europe for at least 550 years, and in England upwards of 200 years. It was long confounded with measles, and only in the nineteenth century was it definitely distinguished from diphtheria. It is most widely diffused in Northern and Western Europe, and in North America, but has failed to establish itself firmly in Africa or any part of Asia, except Asia Minor. Temperate and somewhat humid climates seem to be most favourable to it, but the evidence upon this point is conflicting. In England it is more prevalent in urban than in rural areas, mining districts and several of the large manufacturing towns being most

affected of all. It is probable that the explanation of this is to be found in the greater facilities for receiving and transmitting infection from person to person. Scarlet-fever has a well-marked relation to season. In England the mortality is at its minimum in March and April, and rises to a maximum in October, subject to irregularities if only small numbers or short periods are taken. In New York, however, the curve is almost reversed, the minimum being in September and the maximum in April. The number of attacks varies according to season in the same way as the mortality, but the seasonal range is greater in the attack curve; apparently the attacks in spring are, on the average, more severe, though fewer, than those in autumn.

As to the meteorological conditions favourable to the spread of scarlet-fever, there is wide divergence of opinion. The rise and fall of scarlet-fever epidemics often cover a period of years, and the mortality in any particular week or month must not be regarded as determined solely, or even principally, by the meteorology of that brief season. It seems probable that the tendency to spread is increased by atmospheric humidity and absence of wind, but checked by heavy rainfall.

*Age.**—Children under one year of age, and especially under three months, are comparatively rarely attacked, but the incidence rapidly increases and reaches its maximum in the fifth year of life. After that period it declines steadily year by year. About 45 per cent. of the attacks occur at ages under five years, 40 per cent. between five and ten years, and 11 per cent. between ten and fifteen years. The

* The number of *deaths* from scarlet-fever increases from birth to a maximum in the third year of life, and steadily declines afterwards. 90 *per cent.* of the deaths occur at ages under ten years, and 65 per cent. *under five* years. Further details will be found in a paper on "Age, Sex, and Season in relation to Scarlet Fever" in the *Transactions of the Epidemiological Society for* 1887–8.

average severity of attack, measured by the proportion of fatal cases, is greatest in infancy or in the second year, and diminishes as age increases, but there is an apparent increase in the severity of the (very few) cases that occur in adults after the 15th or 20th year. The lessened liability with increasing age is greater than can be accounted for either by protection afforded by previous attacks, or by diminished exposure to infection.

There is, therefore, a double gain in shielding a child from infection during the first few years of his life. Every year of escape after the fifth leaves him less and less susceptible, until finally he becomes almost immune; and secondly, if he should be attacked, every year that the attack is delayed reduces the danger to life, and also the risk of formidable complications that may become chronic and disabling even if not immediately fatal.

Females are upon the whole more liable than males, but the attacks are somewhat less fatal, and hence up to ten years of age the mortality is higher among males than among females. At ages above ten the female deaths exceed the male, owing, no doubt, to the greater frequency of attack among women who have the charge of children.

Scarlet-fever is for the most part an epidemic disease. Sometimes it will disappear entirely for years, or "sporadic" cases may occur without any serious general prevalence. In certain manufacturing towns, on the contrary, it may be said to be endemic, although subject to frequent epidemic outbursts.

Graves noted that scarlet-fever was prevalent and malignant in Dublin from 1801 to 1804; during the next 27 years epidemics recurred at intervals, but the type was always mild and the mortality slight; in 1834 the disease reverted once more to the old malignant form, but in the last two decennia of the century it again became mild. Several instances are on record in which the type has suddenly changed during an epidemic from mild to severe, or *vice versa*. In some epidemics *the case mortality* is as low as 3 per cent., or even less,

in others it may reach 30 per cent. As a rule the cases are more severe during the early part of an epidemic, and among children more fatal in town than in country, and more fatal to boys than girls.

No adequate explanation has been offered of the causes that determine the rise and fall of scarlet-fever epidemics, and still less of the causes of the variations in type. Seasonal changes, especially meteorological, doubtless have an influence, but this is superadded upon the true epidemic wave. During the inter-epidemic intervals the proportion of susceptible persons increases, but as regards ages above five years the delay lessens the susceptibility, and it does not appear that the intensity of the outbreak bears any relation to the length of the previous interval.

The pathogenic microbe of scarlet-fever, according to Klein and Gordon, is a streptococcus (*streptococcus scarlatinæ* or *conglomeratus*), which they have isolated from the blood and nasal and tonsillar discharge of persons suffering from the disease. These observers have grown this streptococcus in broth, gelatine, agar, milk, and blood serum, in several of which media it gives a characteristic culture. It is pathogenic for mice and rabbits. Gordon believes that both *S. pyogenes* and *S. scarlatinæ* play a part in the causation of scarlet-fever, but that *S. scarlatinæ* is the more important of the two, and occupies a position in the bacteriological kingdom between *S. pyogenes* and *B. diphtheriæ*. Baginsky, Sommerfeld, and Class have also isolated streptococci which they believe to be the cause of scarlet-fever. They are probably forms of *S. scarlatinæ*. Klein further believes that the same organism was found in cows suffering from the Hendon disease, also in a sample of condensed milk that apparently caused an outbreak of scarlet-fever, and in the blood of a monkey that, during an epidemic of scarlet-fever at Wimbledon, presented symptoms of the disease. It is found in the throat secretions of patients in the acute stage, but not in the desquamated cuticle or the urine, or in the

ear discharge which occasionally affects convalescents. It has, however, been discovered in the nasal discharges of advanced convalescents, and in the throat secretions long after apparently complete recovery. This persistence may afford an explanation of the obscure "return cases" of scarlet-fever. It should not, however, be forgotten that a streptococcus occurs in the saliva of healthy persons (*Gordon*).

The period of incubation is usually three or four days, but it would appear that in exceptional cases it may be less than twenty four hours, or as long as seven days. Some authorities believe the usual incubation period to be much longer, but Tonge-Smith's exact observations upon cases which, owing to error in diagnosis, were exposed to infection during transit to hospital in an ambulance, afford strong proof of the accuracy of the estimate given above.

The onset in well-marked cases is sudden, with vomiting, rigors, headache, pyrexia, and sore throat as prominent symptoms. The rash follows in about 24 hours. It is at first punctiform, but becomes diffuse. It is usually seen first about the neck and chest, but may spread over the whole body. The face remains clear of rash though it may be flushed, leaving a pale area around the mouth. The rash occurs most markedly on points of pressure and at flexures. It increases for one or two days and begins to decline in two or three days more. Desquamation begins as soon as the rash disappears, the chest being the first and the hands and feet the last parts to clear. True relapses occur in one or two per cent. of the cases, usually about a month after the onset.

Infection is given off from the first onset and for a period that is seldom less than five weeks, and not unfrequently exceeds two months. It has been the practice to isolate until every trace of desquamation has disappeared from the feet,

Gresswell raised an important question in regard to those persons who have suffered from diphtheria in former years, and in whom acute inflammation of the tonsils is set up by change of weather or trifling exposure. He observed that among those associated with them at such times, diphtheria is apt to occur without discoverable cause; and suggested that the chronic morbid condition may really be a latent form of diphtheria, the occasional recrudescence of which becomes the starting-point for the spread of infection.

Slight cases, in which the symptoms are scarcely recognisable, are extremely difficult of diagnosis. During prevalence of diphtheria any sore throat should be regarded with suspicion, even if no membrane is visible and the constitutional symptoms are wanting. There is no necessary relation between the severity of attack in two cases of which one is infected from the other; the slightest case may impart fatal infection. In doubtful cases, where no membrane can be found, some assistance may be given by the knowledge of the existence of other cases of diphtheria, and paralytic sequelæ may ultimately clear up an obscure diagnosis. The breath and sputa are infectious from the first. Clothing, furniture, and even walls and floors, may retain the virus tenaciously.

Schools afford, as Power observed in 1876, a favourable ground for the spread of diphtheria. There children at the most susceptible ages are brought together for some hours daily in close contact, often in a moist and impure atmosphere, with scanty ventilation; not unfrequently such children use the same articles, towels, slates, pencils, etc., and are brought into intimate contact with each other. Shirley Murphy has pointed out that a marked increase in the number of cases of diphtheria in children of school age followed on compulsory elementary education, and that corresponding with school holidays there is a temporary reduction in the number of notified diphtheria attacks at school ages. Nor is the danger limited to the mere spread of infection, for, as Thorne Thorne showed, a progressive development of virulence and infectiousness is brought about by the aggregation of slight (possibly

unrecognisable) cases among susceptible children at school. Many instances are recorded, especially in districts where throat affections are more or less endemic, commencing with the appearance of cases of sore throat, followed presently by cases of diphtheria, which increase in numbers and severity. The epidemic is usually arrested by closure of the school, often only to break out again, with renewed virulence, as soon as the school is reopened.

Among preventive measures, the first are isolation and disinfection. Doubtful cases should be secluded and no children from infected households should be allowed to attend school. Supervision of 'contacts' should be kept for a fortnight, and if necessary prophylactic inoculation of antitoxin should be undertaken (500 units). Closure of schools is advisable if many cases have occurred among the scholars, or if diphtheria is prevalent in the district, and especially if the school is the means of bringing children from infected villages into contact with others. Milk supplies that are found to be implicated in the spread of infection must be stopped at once, and most rigid precautions should be taken in regard to households connected with the milk trade. Lastly, insanitary conditions should be sought for and remedied.

Bacteriology.—It is now generally held that diphtheria is caused by a bacillus discovered by Klebs in 1883 and isolated by Loffler in the following year. It is a slender rod, straight or slightly curved, and beaded; there are also irregular and club-shaped forms. It differs in size according to its culture medium, but is generally 3 or 4 μ in length. Cobbett and Graham-Smith recognise five morphological types of diphtheria bacilli on young serum cultures—(1) Oval bacilli, with an unstained septum; (2) long, faintly-stained, irregularly-beaded bacilli; (3) long, *regularly-beaded* bacilli—"streptococcal" forms;

(4) segmented bacilli; and (5) uniformly-stained bacilli. All these forms are longer than the pseudo-diphtheria bacilli, more curved, and generally with clubbed ends. In the membrane which is its strictly local habitat in the body—indeed, with the exception of the secretions of the pharynx and larynx, and occasionally in lymph-glands and the spleen, the bacillus is found practically nowhere else in the body—it sometimes shows parallel grouping, lies on the surface of the exudation, and is separated from the mucous membrane by the fibrin. The bacillus possesses at least four negative characters: it has no spores, and no power of motility; it does not liquefy gelatine, nor does it produce gas in cultures. It is stained with Löffler's methylene blue, and shows metachromatic granules and polar staining. Its favourable temperature is blood-heat, though it will grow at room temperature. It is aërobic. Löffler's medium is made by mixing three parts of ox-blood serum with one part of broth containing 1 per cent. of glucose, 1 per cent. of peptone, and ½ per cent. of common salt; the whole is coagulated. Upon this medium the Klebs-Löffler bacillus grows rapidly in 18-20 hours, producing scattered round, white colonies, becoming yellowish. The bacillus grows well in broth, but without producing either a pellicle or turbidity; it can grow on the ordinary media, though its growth on potato is not readily visible; on the white of egg it flourishes extremely well. In a moist condition, apart from the body, the bacillus has a low degree of resistance, but when dry can survive for long periods. The bacillus is secured from the throat by examination of a piece of the membrane or by a swab. Three examinations should be made before concluding that the throat is clear. About *20 per cent.* of all cases of diphtheria offer no *bacteriological* evidence of infection. The bacillus may

exist in the throat of infected persons for long periods, even several months, causing such persons, though apparently healthy, to be infectious. It may also be present in the throats of persons who have not suffered from the disease—"carriers"—and this fact doubtless furnishes the explanation of some sporadic cases and obscure outbreaks.

A *pseudo-diphtheria bacillus* described by Hofmann has somewhat similar characters to the true Klebs-Löffler bacillus, and is frequently found in healthy throats, especially in children of the poorer classes. It differs from the true diphtheria bacillus in the following ways: (*a*) it is thicker in the middle than at the poles; (*b*) forms no acid in glucose culture media; (*c*) does not give Neisser's reaction; (*d*) differs in artificial culture; (*e*) does not agglutinate like B. *diphtheriæ*, and (*f*) possesses no pathogenic action. It is probably innocuous, but in practice it is the safest course to look with suspicion upon any throat harbouring pseudo-diphtheria bacilli.*

Antitoxin treatment of diphtheria.—Diphtheria antitoxin is prepared by taking a month-old culture of the Klebs-Löffler bacillus. This is filtered and the toxin inoculated into the horse in gradually increasing doses until a large degree of acquired

* There are a number of other bacilli from which the true diphtheria bacillus must be differentiated. These include the *B. coryzæ segmentosus*, *B. xerosis*, and a number of "diphtheroid" bacilli, and organisms from nasal and aural discharge. There are, as summarised by Gordon, five chief characters by which the true diphtheria bacillus may be known:—(*a*) The macroscopic and microscopic appearance of the growth on blood serum; (*b*) the behaviour of the bacillus to Löffler's blue, Gram's stain, and Neisser's stain for granules; (*c*) the reaction to litmus of a culture in alkaline broth containing 2 per cent. of dextrose after 48 hours at 37° C.; (*d*) the pathogenic test—1 c.c. of broth culture, 48 hours' growth at 37° C., injected subcutaneously into 200–300 gramme guinea-pig, produces death generally in 48 hours, whilst *post-mortem* hæmorrhagic necrosis and œdema are found locally, the internal organs are congested, the pleural, pericardial, and peritoneal fluids are increased, and the suprarenal capsules are enlarged and engorged with blood; (*e*) the virulence of the organism or its toxin is completely neutralised by a simultaneous dose of diphtheria antitoxin. For purposes of rapid diagnosis, (*a*) and (*b*) are usually accepted.

tolerance has been produced. After injecting, say, 500 c.c. without ill-effect, and the horse having rested for a few days, blood is drawn from the jugular vein into sterilised flasks, in which it coagulates. The separated serum, which averages about half the total blood drawn, is filtered, and tested as to strength of antitoxin value, or as it is termed, "standardised," by observation of its power of immunising a guinea-pig of certain weight against a minimum lethal dose of toxin. It is now ready for therapeutic use, and the patient is injected subcutaneously between the crest of the ilium and the last rib. Strict asepsis must be observed, and the dose should be as large as practicable (2,000-5,000 units). Antitoxin is now very widely used in the treatment of diphtheria, and is increasingly used as a prophylactic in "contact" persons (300-500 units).

The following summary of the Antitoxin treatment of all forms of diphtheria at the hospitals of the Metropolitan Asylums Board, 1895-1903, compared with the results obtained before the adoption of that treatment, affords striking evidence of the efficacy of diphtheria antitoxin:—

	Cases.	Deaths.	Mortality, per cent.
1890-3 (before antitoxin)	7111	2161	30·39
1894 (antitoxin occasionally used) .	3042	902	29·65
1895 . . .	2182	615	28·1
1896 . . .	2764	717	25·9
1897 . . .	4381	896	20·4
1898 . . .	5186	906	17·5
1899 . . .	7038	1082	15·3
1900 . . .	7271	936	12·8
1901 . . .	6499	817	12·5
1902 . . .	6015	714	11·8
1903 . . .	4889	493	10·1

Its value is particularly noticeable among children. Amongst cases in the first year of life the rate has fallen from 61·8 to 37·8, in the second year from 63·1 to 35·4, in the third year from 55·1 to 26·4, in the fourth year from 48·3 to 22·9; and in the fifth year from 39·6 to 20·7.

At the Brook Hospital, MacCombie has kept records showing the results of the antitoxin treatment, with special reference to the day of the disease on which treatment began in order to illustrate the effect of early administration:—

Mortality per cent. in Cases Treated.							
	1897	1898	1899	1900	1901	1902	1903
Cases treated on 1st day of disease	0·0	0·0	0·0	0·0	0·0	0·0	0·0
" " 2nd "	5·4	5·0	3·8	3·6	4·1	4·6	4·2
" " 3rd "	11·5	14·3	12·2	6·7	14·9	10·5	17·6
" " 4th "	19·0	18·1	20·0	14·9	12·4	19·8	16·0
" " 5th day and after	21·0	22·5	20·4	21·2	16·6	19·4	17·3

It is now customary to discharge diphtheria patients from hospital only after two consecutive bacteriological examinations of the fauces have proved negative. In the hospitals of the Metropolitan Asylums Board this results in an average length of residence in hospital of 50 days.

Croup is credited with an annual death-rate of between 0·1 and 0·2 per 1,000 living. There can be no doubt that many deaths from diphtheria and laryngitis have been attributed to croup, and if, as some authorities still maintain, there is a true "croup"—that is, a non infectious membranous laryngitis due mainly to wet and cold, and not followed by paralysis—it is of less frequent occurrence than the death returns would imply. The death-rate from croup is declining, and the decline is probably due to improved diagnosis. Outbreaks of diphtheria are commonly attended with cases of so-called "croup," which upon investigation prove to be diphtheritic.

The seasonal curve of deaths attributed rightly or wrongly to croup has its maximum in the cold months from December to March. It is much later than that of diphtheria, and approximates more closely to the laryngitis curve. In the distribution

as regards age and sex a further difference from diphtheria is noticeable. Croup is more fatal to males than females upon the whole, the mortality among females being lower up to fifteen years of age. The highest mortality in both sexes occurs in the second year of life. In all these respects "croup" is allied to laryngitis rather than diphtheria.

Erysipelas occurs in all parts of the world, but more in temperate regions than elsewhere (*Hirsch*). In North America it has repeatedly taken the form of widespread and malignant epidemics, and in England and elsewhere virulent outbreaks often originated in former years in hospitals, especially in surgical wards, where cleanliness, ventilation, air-space, drainage, and other sanitary essentials were neglected. At the present time outbreaks of this kind are rare, and erysipelas is chiefly met with in sporadic form. In its seasonal curve, and also in its local attachments and periods of recurrence, it is closely allied with scarlet-fever and diphtheria, and still more closely with puerperal fever. It attacks males more than females, and kills more in early infancy than at any other period of life, although the mortality increases again after twenty-five years of age. After inoculation the incubation is usually from one to three days. It is not certain whether the disease is ever acquired except through some breach of continuity of skin or mucous membrane, but the occurrence of so-called "idiopathic" (non-traumatic) erysipelas points to this. The pathogenic microbe is a streptococcus, readily cultivated, and reproducing the disease upon subsequent inoculation.

Relapsing fever, "famine fever," or "bilious typhoid," was first recognised clearly in Ireland in the eighteenth century, and still has its principal focus there, although epidemics are not unfrequent in Scotland, and have occurred in England, Northern Europe, the Levant, India, and several eastern countries. It occurs often in conjunction with typhus and is apparently closely related to it in etiology. Epidemics of the two diseases frequently coincide, or one follows the other closely, or sporadic cases of the one are observed during prevalence of the other. Neither *climate* nor weather has been found to influence it in *any marked* degree, nor has it any apparent relation *to soil.* Overcrowding and want of food are powerful

predisposing causes, especially the latter, which Murchison thought was capable of originating the disease, but many epidemics have occurred without noteworthy privation. The wealthier classes are almost exempt, and females are less susceptible than males. Under favourable conditions it appears in districts that have long been free from it, and in many such cases no history of imported infection can be made out, but nevertheless the theory of spontaneous origin cannot now be accepted.

The disease is highly infectious, but appears to be capable of transport through the air for short distances only, though it readily attaches itself to fomites. A specific spirillum was discovered by Obermeier in the blood of patients during the febrile stage only, and inoculation with blood containing spirilla has been found to reproduce the disease in men and monkeys. It is possible that there is some relation between Obermeier's spirillum and the trypanosomes recently found in relapsing fever. The protection afforded by an attack is slight. Only about 5 per cent. of the cases terminate fatally, but convalescence is slow.

Typhus has only comparatively recently been distinguished from enteric fever, but the two diseases are widely different in their etiology and epidemiology.

Typhus epidemics have been recorded in considerable numbers for several centuries past, more especially in times of war and famine, and were common in the seventeenth century and up to 1815. The only great epidemic in Europe since that time was in 1846-7. Ireland has been from earliest times one of the chief centres of the disease, Russia being another. Although for the most part limited to cold and temperate climates, typhus is by no means unknown in many hot countries, but usually at considerable elevation. The different habits of life, and especially the abundant ventilation, which prevail in warm countries may help to account for their comparative immunity, but as the effect of season remains marked, there is probably some further influence at work. In former times, epidemics of typhus frequently reached England, appar-

ently by invasion from Ireland; but for many years past typhus has almost entirely disappeared from the southern and midland towns of England, although still occurring in the large towns of the north and of Scotland, especially those containing a large Irish population. The last general epidemic in Ireland was in 1862-4.

Cases of typhus are most numerous in winter and spring, and in warm countries epidemics seldom occur at any other season. In countries in which typhus is common, however, the origin and course of epidemics are not checked by either extreme of temperature.

Telluric conditions are not known to have any influence.

The great predisposing causes of typhus are overcrowding, want of ventilation, filth, debility, and privation. Wars and famines in former centuries were frequently followed by outbreaks of fever, among which typhus was prominent. "Gaol fever" (typhus) was common in English prisons up to the last century, owing to their filthy and overcrowded state. Better ventilation of vessels has rendered "ship fever" almost unknown, but accidental repetition of the old conditions, even in recent years, has led to fresh outbreaks of typhus. Typhus broke out among the British troops in the Crimea in 1854-5, and among the besieged in Metz in 1870. In Ireland the years of famine and distress have been attended with typhus.

It is not clear that any race or class is especially susceptible, or the reverse, apart from the conditions under which they live; but for the reasons already stated, the poorest classes suffer by far the most from typhus.

Age and sex.—The mortality from typhus increases from childhood to about fifty years of age, and then declines somewhat. It is greater among males, except, perhaps, in childhood. Handford finds that the susceptibility is greatest in the ten to fifteen years' age-period, but that the case mortality, *i.e.* the proportion of deaths to attacks, is at its minimum in this period,

and rapidly increases at later ages. Spear has called attention to the mildness of the symptoms in children, owing to which the initial attacks in an outbreak are liable to escape diagnosis.

The incubation period seems to be very variable, and, according to Murchison, may be only a few hours or as long as three weeks or more. It has been observed to be short in certain cases after exposure to the poison in a concentrated form. Perhaps twelve days may be taken as the most usual duration. The rash appears within a week after the onset, and as a rule, on the fourth or fifth day. The disease generally terminates in death or convalescence about the end of the second week, and isolation may be terminated in ten days or a fortnight more. The mortality averages about 20 per cent., but varies with the age, condition, and surroundings of the patient, and with the epidemic.

Infection is given off by the breath, probably by the exhalations from the skin and mucous membranes, and possibly by the excreta. Some have suggested that the disease is spread by vermin, especially fleas. According to Murchison, the infectivity is more active after the first week. The air immediately surrounding the patient appears to be infectious, but its virulence is rapidly lost by diffusion—a result that may be attributed to dilution, or desiccation. The poison clings readily and strongly to clothing and other fomites, but has not been shown to be conveyed by water, or by milk or other food. Doctors and nurses in typhus wards rarely escape for long unless protected by a previous attack. Second attacks are rare.

Typhus is probably acquired by inhalation of the poison, whether from contact with the patient, breathing the air in his immediate vicinity, or by the intervention of fomites. The powerful predisposing influence

of overcrowding and want of ventilation may be explained by the facilities which they give for infection and for concentration of the poison, as well as their effect in rendering the individual more susceptible.

No pathogenic microbe is yet known, but it may safely be inferred from analogy that, without the presence of a specific poison, no intensity of the favouring conditions can originate an outbreak of typhus. It is, nevertheless, true that the disease often makes its appearance suddenly among overcrowded and filthy communities—on shipboard, for example—in instances where no previous case can be traced.

Typhus is essentially a preventible disease. Isolation of the patient, disinfection, and quarantine of persons exposed to infection will rarely fail to arrest a localised outbreak. Cleanliness and ventilation are auxiliaries of the first importance.

Enteric or typhoid fever was differentiated from typhus in 1850 by Jenner. It is a disease of practically world-wide distribution, but is less prevalent in tropical regions than elsewhere. In England it is decreasing in prevalence, and now contributes not more than 0·1 to the average general death-rate. For instance, the death-rate from this disease in 1904 in England and Wales was 0·09, which shows a marked decline on previous years. In 1871-80 it was 0·32, and in the decade following 0·19. In London in the decennial period 1893-1902 it was 0·15.

Season.—In England the greatest prevalence occurs in October, and the minimum in May or June. The autumnal maximum is very general, but the exact position of the summit of the curve varies in different countries; in New York it occurs in September.

Weather.—High or low temperature of the air has in itself no clear relation to enteric prevalence, nor

has the rainfall, but instances are recorded in which hot and dry summers were followed by high mortality from the disease, upon the occurrence of rain, and the reverse after cold and wet summers. It is probable, in view of the frequent relations between telluric conditions and enteric fever, that meteorological conditions act mainly by modifying the temperature and moisture of the soil, and that rainfall may either increase or diminish the chances of an outbreak according to the previous condition of the ground.

Soil.—Pollution of the earth by animal matter, especially if excrementitious in origin, is conducive to the endemic or epidemic prevalence of enteric fever. Pettenkofer and Buhl have traced a connection between the movements of the ground water and the occurrence of enteric fever sickness and mortality in Munich, which has been confirmed by further observation in Berlin and other parts of Germany, and elsewhere. "The total of the cases of sickness and death from typhoid falls with the rise of the subsoil water, and rises with the fall of it; . . . the level reached by the disease is not in proportion, however, to the then level of the subsoil water, but only to the variation in it on each occasion; or, in other words, it is not the high or low level of the subsoil water that is decisive, but only the range of fluctuation" (*Hirsch*). This relation is so constant as to leave no room for doubt as to its reality and significance in the localities in question, but it does not appear to hold good in England, and Fodor has found exactly the reverse in Pesth. In many places where enteric fever occurs, the subsoil water is so deep and its movement so trifling that there is little probability of its producing any material effect. In Munich the soil is porous, the ground water high, and, until recently, leaking cesspools are said to have been universal. As *Buchanan* has pointed out, the purity of water in

wells is liable to be affected by changes in the level of the ground-water, and the readiness with which enteric fever is spread by means of specifically polluted water must not be lost sight of.

Air does not appear to carry the poison of enteric fever under ordinary conditions even for the shortest distances, and the chances of infection by mere proximity to a patient are slight, though occasionally instances suggestive of this are met with. Infection from the sick to the healthy by direct or indirect contact is, of course, one of the commonest means of spreading the disease; water and milk being others.

Water.—While water polluted even with excremental filth has often been drunk for years by numbers of people with perfect impunity so far as the appearance of enteric fever is concerned, contamination with the excreta of a case of enteric fever has over and over again been found to result in widespread outbreaks of the disease, the incidence of which in such instances exactly follows the distribution of the water, and affects only those persons who drink it. Such outbreaks rise suddenly to considerable proportions, but decline gradually. Corfield collected particulars of more than 50 water-borne epidemics of typhoid between 1864 and 1902. Some have arisen from specific pollution of shallow wells, as at Guildford in 1867, in the Uxbridge Rural District in 1882, at Hitchin in 1883, at Beverley in 1884, etc.; others from the pollution of deep wells. Thus an outbreak of enteric fever at Redhill and Caterham in 1879 was traced by Thorne Thorne to pollution of one of the well-adits at the Caterham Waterworks by the excreta of a workman suffering from a mild attack of enteric fever, the organic impurity of the water, as shown by analysis, being extremely small. Another case of infection of a deep well was at Houghton-le-Spring, in

Durham, in 1889. The large outbreak at Worthing in 1893 (1,315 cases) was due to the consumption of water from a new heading, which was contaminated by sewage. The water borne poison is not dependent upon the organic matter in the water, but upon the specific pollution, which need not necessarily be large in quantity.

Innumerable other instances are on record in which direct and obvious excretal contamination of wells, springs, streams, cisterns, reservoirs or water-mains has been followed by enteric outbreaks upon a large or small scale, according to the number of persons drinking the water. As illustrations may be mentioned the outbreaks at Caius College, Cambridge, in 1873, at King's Lynn and Maidstone in 1897, and at Lincoln in 1905. Buchanan found that in the case of Caius College, the water in the main at Tree Court, which was chiefly affected, was contaminated by suction into it, during the periods of intermission of supply, of foul air from a soil pipe, through a "weeping pipe" which supplied the trap on the waste-pipe of the safe-tray of a water closet, the trap being liable to siphonage. The King's Lynn outbreaks (1892 and 1897) were traced to pollution of the sources of the water supply, namely, the river Gaywood, with typhoid excreta, and the same applies to the great outbreak at Maidstone (1,847 cases) in 1897, which was believed to have been caused by pollution of the springs by excremental matter from a colony of hop pickers. In both these cases the filtration of the water as delivered was inefficient. The outbreak at Lincoln in 1905 included some 900 cases, and commenced towards the end of January. The river Witham and its tributaries, from which the supply was taken, were polluted "by drainage from land highly cultivated, and occasionally *manured with* night soil." The effluent from a

sewage farm discharged into the river above the intake. In the autumn of 1904, and in January, 1905, there were a number of cases of enteric fever in Lincoln, and, therefore, opportunity for the typhoid virus to gain access to the water supply, which, owing to increased acceleration due to heavy demands, was not effectually filtered in the filter-beds. The result was a water-borne outbreak of enteric fever, chiefly affecting households which did not boil their drinking water. Many confirmatory observations have been made of places in which enteric fever, once endemic, has become rare coincidently with the substitution of a pure for an impure water supply. Thus at Millbank Prison, artesian well water was substituted for Thames water in 1854, and the previous endemic prevalence of enteric fever disappeared.

In several of the cases mentioned above, the proof of specific pollution was incomplete, and it has been held that sewage-polluted water may acquire the property of causing enteric fever in those who drink it, without the access of enteric excreta. Even in country districts, where the movements, identity, and health of every person coming into the locality are easily traced, it has often been found impossible to obtain evidence of specific pollution of water that was nevertheless instrumental in spreading enteric fever. On the other hand, it is clear that something beyond simple excremental pollution is necessary to account for the sudden acquisition of morbific properties in a water that has long been polluted; and, moreover, attacks of enteric fever may be so mild as to escape recognition, nor is it safe to disregard the possibility that the specific poison may gain access in ways as yet unsuspected.

Shirley Murphy has found distinct increase in *notified* enteric attacks in London following floods

above the water-intakes, and he has further pointed out that disease carried by water or milk may affect so few persons, or be in so mild a form, as to escape recognition.

It is necessary to remember that the urine of the patient as well as the bowel discharges may contain the infective bacillus. Horton Smith has shown that the urine is infective in one in four cases, and most frequently towards the end of the disease and during convalescence. In one recorded case the typhoid bacillus was found in the urine eight months after convalescence. Other observers have found bacilluria of this kind present in between 30 and 40 per cent. of the cases examined.

Food.—Milk was first recognised as a medium for the dissemination of enteric fever in 1857. Many instances have since been recorded, in England and other countries, the infection being sometimes traced to the use of polluted water for washing the cans or diluting the milk, sometimes to the milk being infected more or less directly by a person suffering from enteric fever (see page 132). Oysters have on many occasions recently been suspected of conveying the infection of enteric fever. In 1894 Newsholme reported a number of such cases, and in the same year an outbreak of the disease occurred at a college in Connecticut, traced to oysters. In this country, between 1894 and 1902, increasing evidence was forthcoming in confirmation of this channel of infection, and in the latter year occurred the well known outbreaks at Winchester and Southampton, traced to the consumption of polluted oysters at mayoral banquets (*Bulstrode*). It is now well understood that oysters fattened on sewage contaminated beds may cause disease in persons eating them (see page 120). Fried fish (*Hamer*), ice-cream, watercress, and other foods have also carried enteric

infection. When the disease is thus contracted it is characterised by multiple cases in houses, and an exceptional age-incidence.

Drain effluvia, sewer gases, and emanations from manure heaps and other filth accumulations, are often regarded as directly causing enteric fever. That they are powerful predisposing causes is beyond doubt, and it may be supposed that persons exposed to their influence become more susceptible to the enteric poison. Alessi has shown experimentally that this is true of rats, rabbits and guinea-pigs, after exposure to the effluvia from cesspools or excreta. The incidence of attack is heaviest upon households or districts in which drainage defects, or insanitary privies and earth closets, exist, although it is often difficult to dissociate their influence from that of impurity of soil and water. Buchanan has shown that in the large English towns improved drainage has greatly lowered the death-rate from enteric fever. In towns that have been newly sewered, without due attention to the disconnection and trapping of house drains, enteric fever has sometimes become far more prevalent in large houses upon high ground, tenanted by the wealthier classes, than in the poorer districts down below, in which very commonly there were no drain-inlets within the houses. Here, however, the presence of enteric excreta in the sewage may be suspected. Precisely the same conditions are recognised, and with equal justice, to be conducive to outbreaks of diphtheria, a totally distinct disease, and in either case the presence of a specific poison is doubtless essential to the manifestation of the specific disease, be its mode of access what it may. Grossly insanitary conditions may exist for years without any outbreak of either disease. Men working in sewers do not appear to be specially liable to enteric fever, nor do those employed in scavenging in pail-closet towns, although

they come into close and frequent contact with enteric excreta.

Locality.—Enteric fever is more prevalent and more fatal, at all ages, in towns than in the country, and often fixes persistently upon one district, where the predisposing conditions mentioned elsewhere will usually be found to exist. In such districts new-comers are especially liable to attack; this has been observed on a large scale as regards soldiers newly arrived in India. It seems probable that some sort of acclimatisation is at work, relative immunity being conferred by repeated minimal infection. As a rule, but by no means always, the areas in which enteric fever is endemic are occupied by the poorest class, among whom insanitary conditions abound, and little care is taken for preventive measures.

Age.—According to Handford, "the susceptibility to enteric fever decreases with age from the earliest years onwards, though the decrease is slight between fifteen and twenty-five, whereas the risk of a fatal termination steadily increases with age." The Registrar-General's figures, however, tend to show that the fatal incidence is less during the first five years of life than between five and ten years. The registered mortality is low in infancy, high in the second to the fifteenth year, and then rises further to a maximum between 15 and 35 years, after which it falls permanently. It is probable that true enteric fever is rare among infants and young children, and that many of the cases recorded at those ages are due to faulty diagnosis.

Sex.—More males than females die from enteric fever, but the mortality is greater among females from the fourth to the twentieth year of age. The susceptibility, according to the Registrar-General, is greater among males from about the fifth to about the twenty-fifth year, and greater among females at

all other ages. The average severity of attack is somewhat greater among females; 18·8 per cent. of female cases end fatally, and 17·1 of male cases.

The most frequent mode of infection is by the mouth, the virus either being contained in water, milk, or other food, or conveyed more directly by the unwashed hands after contact with infected matter. That the excreta are infective is certain, and it is possible that infection is sometimes carried by the breath. Enteric patients are sometimes treated in general hospitals side by side with other cases; but with scrupulous cleanliness, especially as regards the nurse's hands, and any clothing that may have become soiled in however minute degree with the patient's discharges, it seems that, although nurses are not unfrequently attacked, the infection has little tendency to spread to other patients. It is otherwise in crowded homes, and there can be no question that direct personal contagion has been the cause of not a few of the smaller outbreaks of the disease, and of many secondary cases in the larger epidemics (*e.g.* in the Lincoln outbreak of 1905).

The incubation period is variable, from two or three days to three or even four weeks, perhaps most usually twelve to fourteen days. The insidious mode of onset renders exact determinations difficult. The incubation is often short when the poison is introduced by water or milk. In some of Budd's cases it was only two or three days, at Guildford ten or eleven days, in the Caterham outbreak fourteen days. Jancken records an instance in which a body of soldiers, not otherwise exposed to infection, marched through two villages in which enteric fever was rife, and drank freely of water. Two days later 3 were attacked by enteric fever; then 7, 6, 0, 4, 5 in successive days, and 7 more within the fortnight—32 in all. The onset was sudden, but the course mild. Another section of the

troops passed through the same villages without drinking, and escaped illness.

The duration of illness is usually about three to four weeks, but may be protracted by relapses. Second attacks are not uncommon.

The greatest care is needed to prevent all risk of contamination of milk supplies or water. The disposal of the excreta is a matter of great importance. They should be disinfected and disposed of at once. In the country it is customary to bury them away from houses or sources of water supply; in towns they are usually dealt with like other excreta, but where pail closets are used enteric excreta may be separately collected and cremated. The urine, as we have seen, often contains the bacilli.

Bacteriology. In 1880-81 Eberth announced the discovery of the typhoid bacillus in cases of clinical enteric fever. In 1884 it was first cultivated outside the body by Gaffky. Since then other organisms have been held responsible for the causation of the disease. In 1885 the *B. coli communis* was recognised, and it has been a matter of some debate among bacteriologists as to how far these two organisms are the same species, and interchangeable. There is evidence on both sides of the question, but bacteriologists generally regard the Eberth Gaffky bacillus as the specific cause of typhoid fever, though complete proof is still wanting. The bacilli appear as rods, 2 4 μ long. 5 μ broad, having round ends. Sometimes threads are observable, being 10 μ in length. The bacilli differ in length from each other, but are approximately of the same thickness. Round and oval cells constantly occur even in pure culture, and many of these shorter forms appear to be identical in morphology with some of the many forms of *B. coli.* There are no spores. Motility is marked, due to *some five to twenty* flagella of varying length. The

flagella are both terminal and lateral, and are elastic and wavy.

The organism may be isolated from the ulcerated Peyer's patches in the intestine, from the spleen, the mesenteric glands, and the urine. Owing to the mixture of bacteria found elsewhere, it is generally most readily isolated from the spleen. For this purpose the whole spleen is removed, and a portion of its capsule seared with a hot iron to destroy superficial organisms. With a sterilised knife a small cut is made into the substance of the organ, and by means of a sterilised platinum wire a little of the pulp is removed and traced over the surface of agar, on which growth occurs in 24 hours at 37° C. The bacillus grows on all the ordinary media. It is decolorised by Gram's method. The typhoid bacillus is capable of saprophytic existence in soil, dust, water, milk, and other natural media. It can survive in ordinary earth for two months, on sterilised linen for 60 days, on woollen cloth for 80 days, in sterilised water 196 days, in certain soils 400 days. Wright has prepared a vaccine from a virulent 24 hours' culture in broth. It is killed by heating at 60° C. for five minutes, and is injected hypodermically in the flank.

The typhoid bacillus agglutinates with serum from a typhoid patient, and this has been used as a bacteriological aid in diagnosis. It is known as *Widal's application of Gruber's reaction*, and is carried out in the following way :—A few drops of blood are drawn from the lobe of the ear or finger of the patient; the serum, which exudes as the blood coagulates, is then diluted with about 9 parts of neutral bouillon. A drop of this dilution is mixed with an equal quantity of a typhoid broth cultivation of 18 to 24 hours' growth made from a virulent culture. Under the microscope it may be seen whether the reaction is positive or negative. If in the mixture of serum and of culture the bacilli become immotile and also become agglutinated, or grouped together in colonies, the reaction is positive. If, however, they remain, as they do in

healthy blood serum, motile and scattered, the reaction is negative. The Widal reaction is obtainable in about 70 to 80 per cent of the cases between the 4th and 14th day of the case and in 90 per cent. of the cases during the third and fourth weeks.

Simple continued fever is still assigned as the cause of a considerable number of deaths, but is steadily losing ground year by year with improving diagnosis and certification. Many of the deaths so returned are probably due to enteric fever, others to septic conditions, pneumonia, etc. Longstaff has shown that the seasonal mortality curve for "simple continued fever" is very different from that of enteric fever, and resembles the typhus curve rather closely, having its maximum in winter and spring.

Epidemic diarrhœa* is returned as the cause of a death-rate that steadily averaged 0·9 per 1,000 from 1850 to 1880, and in 1904 was, for England and Wales, 0·86 per 1,000. In towns it is much higher (1·2 per 1,000) than in rural districts (0·46). In London, from 1893-1903, it had an average of 0·80. In many cases diarrhœa is merely symptomatic, but the existence of an epidemic disease of which diarrhœa is *the* prominent manifestation is now recognised. Much light has been thrown on the subject by Ballard, Newsholme and other observers.

Density of population. Epidemic diarrhœa is essentially a disease of towns, or, in more general terms, of crowded areas. The diarrhœa death rate in 1903 among children 0-5 years of age was 6·3; in urban counties it was 7·7 and in rural districts 3·1. The disease is ordinarily twice as fatal in urban as in rural counties and more dangerous to boys than girls. In counties such as Dorset and Wilts, the mortality

* Under this term are included all forms of zymotic diarrhœa and epidemic enteritis. The Royal College of Physicians (1900) laid down that "gastro-enteritis," "muco-enteritis," "gastric catarrh," and such synonyms of epidemic diarrhœa in medical certificates of death should be discarded. The College regarded epidemic diarrhœa as a general disease of a specific character in the same sense as enteric or other fevers, and therefore authorised the use of the terms "epidemic enteritis" or, if preferred, "zymotic enteritis" or "epidemic diarrhœa," to designate the disease in its various forms and degrees.

(among children 0-5 years) in 1903 was below 2 per 1,000, whereas in Warwickshire it was 8·8, in the East Riding 8·9, and in Lancashire 9·13.

An analysis of the diarrhœa mortality in the various counties according to their average density of population gives a similar result. Thus, in 1871-80 the mean annual diarrhœa mortality per 1,000 at ages under five years was

In 6 counties with more than	4 acres per person .	2·6
„ 9 „ „ „	3 to 4 „ „ „ .	3·6
„ 12 „ „ „	2 „ 3 „ „ „ .	4·2
„ 11 „ „ „	1 „ 2 „ „ „ .	4·8
„ 6 counties with less than	1 acre „ „ .	7·1
In all England and Wales, with an average of	1·5 acre „ „ .	5·6

In 1898-1902 the rate was 11·5 in urban districts and 5·0 in rural. Urban conditions are favourable to the disease, chiefly because of some or all of the following :—

Density of buildings upon an area increases the tendency to diarrhœa mortality, in addition to the density of population that usually, though not always, accompanies it. It is chiefly a disease of urban life.

Elevation of site tends to reduce diarrhœa mortality, but only in the same degree that it affects infant mortality from all causes.

Lack of ventilation and light is conducive to diarrhœa mortality. Among the common conditions that are harmful in this way are narrow dark courts and streets, obstructive walls or buildings, back-to-back houses, overcrowding, and neglect of ventilation of rooms.

Lack of cleanliness has a similar effect, and is usually found in association with the above, particularly in houses. But further, towns which have adopted the water-carriage system of sewerage have less diarrhœa than those which retain other methods of

removal of excrement. Towns also which have the most effectual scavenging arrangements, including the methods of removal of house refuse, have the least epidemic diarrhœa.

Foul air from sewers, cesspools, and filth accumulations of any kind promotes diarrhœa mortality. Smoke and mere chemical effluvia seem to be inoperative.

Drinking-water may cause outbreaks of diarrhœa, independently of season, but is not responsible for ordinary epidemics of summer diarrhœa.

Soil. Diarrhœa mortality is low in places built upon solid rock, high where the soil is loose and porous. Sand and deep mould are the worst, clay is far better. Organic pollution of the soil, whether vegetable or animal in origin, is a most potent factor, and occurs especially upon such sites as "made ground," pervious soils, town refuse, market gardens, or in soil polluted by leakage from drains or cesspools. Dampness of soil, accompanied by aeration, is the most favourable condition for diarrhœa, dryness or saturation being alike preventive.

Temperature.—High temperature of the air has long been observed to be associated with high diarrhœal mortality, and the reverse with low air temperature, but Ballard shows that the relation is indirect. The maximum mortality by no means necessarily coincides with the highest readings of the air-thermometer. The temperature of the soil, being a less sensitive indicator and more steady in its record, is on the whole a safer guide.

Ballard concluded that—

"(*a*) The summer rise of diarrhœal mortality does not commence until the mean temperature recorded by the 4 foot earth thermometer has attained somewhere about 56° F., no matter what may have been the temperature previously attained *by the atmosphere* or recorded by the 1-foot earth-thermometer.

"(*b*) The maximum diarrhœal mortality of the year is usually attained in the week in which the temperature recorded by the 4-foot earth-thermometer attains its mean weekly maximum.

"(*c*) The decline of the diarrhœal mortality . . . coincides with the decline of the temperature recorded by the 4-foot earth-thermometer, which temperature declines much more slowly than the atmospheric temperature or than that recorded by the 1-foot earth-thermometer.

"(*d*) The influence of the atmospheric temperature, and of the temperature of the more superficial layers of the earth, . . . is little, if at all, apparent until the temperature of the 4-foot earth-thermometer has risen as stated above; then their influence is apparent, but it is a subsidiary one."

Tomkins found that epidemic diarrhœa did not occur in Leicester until the temperature of the 1-foot thermometer reached 60° F.

Rainfall is operative by its cleansing effect upon the atmosphere, by laying dust, and by its reducing effect upon the temperature of the soil and the atmosphere. Diarrhœal mortality is greater in dry and less in wet seasons. Deficiency of rainfall plus high atmospheric temperature are probably the two chief external conditions favourable to epidemic diarrhœa. *Wind* tends to reduce diarrhœa mortality, calm in the diarrhœal season promotes it.

It was upon broad facts such as these that Ballard, in 1887, based his "provisional hypothesis":—

That the essential cause of diarrhœa resides ordinarily in the superficial layers of the earth, where it is intimately associated with the life-processes of some micro-organism not yet isolated.

That the vital manifestations of such organism are dependent, amongst other things, perhaps, principally upon conditions of season and on the presence of dead organic matter, which is its pabulum.

That on occasion such micro-organism is capable *of getting* abroad from its primary habitat, the earth, *and having* become air-borne obtains opportunity for

fastening on non living organic material (especially food whether inside or outside the body), and of using such organic material both as nidus and pabulum in undergoing various phases in its life-history.

That from food and from organic matter in certain soils it can manufacture a virulent chemical poison, which is the material cause of epidemic diarrhœa.

Social position.—By far the greatest incidence is upon the poorest class, the artisan and lower labouring classes.

Food, and particularly milk, may "ferment" or become contaminated by exposure to dust or filth emanations, and thus cause diarrhœa. Breast-fed children are remarkably exempt, and those partially breast-fed come next; the mortality is much higher among children artificially fed, and especially if fed by the bottle. On the whole there is evidence to show that infantile diarrhœa is usually a form of food poisoning.

Maternal neglect. The mortality among illegitimate children is higher than that of legitimate children from all causes, but the excess is greatest in regard to diarrhœa. The difference is most marked in years of low epidemicity, and tends to disappear in years of high diarrhœa mortality, but in the latter the average age of attack is earlier among illegitimate children. Occupation of mothers from home contributes to neglect and improper, irregular, and artificial feeding of infants.

Age.—Diarrhœa is fatal at both extremes of life. The first year of life, especially from the third to the ninth month, has by far the greatest mortality. In 1871-80, 63 per cent. of the deaths attributed to diarrhœa were at ages under one year, 80 per cent. under two years. It was by far the most fatal of the infective diseases in infancy, and caused a mortality of over 25 per thousand births. In 1881-90 the

mean mortality rate showed further decline, but the rate under one year decreased more slowly than in any other year under five. From infancy the mortality diminishes until about the 20th year, after which it again increases until the end of life. The liability to attack seems to be greater in the second year than the first, and at all events is far greater in the first two years than in the third or later years. It is comparatively small in the first three months, and probably increases up to the end of the first or beginning of the second year. No age is exempt from attack, but only severe and acute attacks kill at ages between infancy and old age. Tomkins states that "infants and young children form only a small proportion of those attacked, although they furnish nearly the whole of the deaths."

Sex.—The mortality is greater among females from the third to about the 45th year, but greater among males in infancy and old age. The liability to attack, however, is greater among males at all ages.

Season.—Fatal diarrhœa occurs at all seasons, but always increases greatly in summer. In London the mortality curve shows a slight rise throughout June, rapidly increasing in July, and reaching its maximum in the first week of August, after which it again falls steadily throughout September and October. During the rest of the year there is little variation. An outburst of epidemic diarrhœa occurs every year, but the date and intensity of the epidemic vary considerably from year to year, and according to locality. The relation to temperature and other atmospheric and telluric conditions have already been discussed. There is very frequently an alternation of years of high and low diarrhœal mortality, but a simple explanation of this is usually to be found in the meteorological records of the summer months, there

being coincident alternation of hot, dry summers with others which are cool and wet.

Locality.—Diarrhœa is endemic in many large English towns, notably Leicester and Preston, and causes heavy mortality annually. Others, such as Bristol, Derby, and Halifax, are affected much less, though all, as in the Metropolis, show the summer rise every year.

Previous health affects the chances of recovery more than the liability to attack. The incubation is apparently very short, from a few hours to a day, or at most two days. Half the fatal cases terminate within a week, and the course is more rapid in the later periods of an epidemic (*Ballard*). Characteristic pathological changes are found in the kidneys as well as in the intestines, a fact that goes far to prove the specific character of epidemic diarrhœa. Pneumonia is common and fatty degeneration of the liver almost invariable.

In many instances diarrhœa has appeared to be highly infectious by means of the excreta, but this is not always the case.

Outbreaks of diarrhœa occur from time to time, especially in hospitals and other public institutions, which cannot be referred to climatic conditions, but upon investigation are traced to articles of food, and especially to water and milk Water may acquire the power of causing diarrhœa in many ways, including the presence of suspended mineral matter, such as clay or mica (*Parkes*); excess of dissolved mineral matter; suspended or dissolved sewage matter or other animal impurity, especially if undergoing putrefaction; suspended vegetable matter, absorption of fœtid gases, including sulphuretted hydrogen and "sewer gas." Milk is a frequent cause of diarrhœa, owing either to fermentative changes in itself, or to contamination *by specific poison or* effluvia. An outbreak at Moor-

fields Hospital was traced to butter. Putrid food of any kind tends to cause diarrhœa, and fish is especially prone to be injurious if not fresh. Lastly, specific diseases must be mentioned in this connection, as for example the Welbeck cases described in an earlier chapter.

Bacteriology—In 1885 Escherich published his researches on *Bacillus coli communis*, and since that date many authorities have maintained that this organism is the causal agent of epidemic diarrhœa. Booker, on the other hand, as the result of investigation, concluded that many different varieties of bacteria are concerned in the etiology of the summer diarrhœas of children. He considered "streptococcus enteritidis" and *proteus vulgaris* the most important. In 1895 Klein isolated an organism from the evacuations of patients suffering from an epidemic of diarrhœa at St. Bartholomew's Hospital, which he named *B. enteritidis sporogenes*,* and which he believes to be the cause of epidemic diarrhœa. *B. enteritidis sporogenes* is widely distributed, and occurs in normal and typhoid excreta, in sewage, manure, soil, dust, and milk. It has been frequently found in the dejecta of patients suffering from epidemic diarrhœa. It fulfils in a somewhat exceptional degree the requirements suggested by Ballard. But the same is true of *B. coli*, and the question is therefore *sub judice*.

Influenza stands almost alone in its purely epidemic or pandemic occurrence, with little trace

* *B enteritidis sporogenes* (Klein) is an anaërobic bacillus: 1·6–4·8 μ long, and 0·8 μ broad; stains by Gram's method and ordinary stains. Motile; spore formation present; large oval spores often situated near one end of bacillus; grows well on gelatine and agar. In the former gas is produced and the gelatine liquefies. It grows well in milk. After thirty-six hours of anaërobic incubation at 37° C. the surface is covered with stringy, pinkish-white masses of coagulated casein enclosing a number of gas-bubbles. The main portion of the tube of milk contains a colourless thin, watery whey, with a few casein lumps here and there adhering to the sides of the tube. The whey has a smell of butyric acid, and is acid in reaction. It contains many bacilli.

of endemic localisation. Much confusion has arisen from the prevalent misapplication of the term influenza to severe catarrhs, infectious or otherwise. Many epidemics of true influenza have been observed during the last few centuries, spreading over a greater or less portion of the globe. Although there is clear indication of preference for lines of traffic, the progress of an epidemic is highly irregular. It appears simultaneously at widely separated points, often leaping over or avoiding entire countries, perhaps to appear in them later. It may be limited to particular towns or villages, sometimes even to a small section of the population in one part of a town. The advance is frequently rapid, but not more rapid than human traffic, and at other times its progress is slow and halting. The pandemic of 1889 was first heard of in Siberia, in May, and had spread to almost every part of Europe before the end of the year. It reached London late in December, and in the course of the next three months diffused itself over England.

The epidemic quickly reaches its maximum limits in a given centre, owing probably to its infectiousness and short incubation, and the susceptibility of the greater part of the population. It seldom remains longer than a few weeks in any locality, but may return in the course of the same pandemic. The interval between epidemics is irregular. Parsons states that major epidemics occurred in England in 1803, 1833, 1837-8, 1847-8, and minor epidemics about every three years. From 1860 onwards these practically ceased, until 1889, when a new series of epidemics began, each covering almost the whole country, at intervals of about a year, and which in ten years destroyed no fewer than 87,767 lives in England and Wales. In the three years 1901-3, the influenza death-rate averaged 195 per million, against an average rate of 408 *per million in the* three years ended with 1900.

Speaking generally, influenza appears to be more fatal in the country than in the town. (*Tatham.*)

In the same district the type of the epidemic remains fairly constant as regards intensity, severity, and perhaps the tendency to one or other group of local symptoms or complications. There is, however, considerable variety in different centres during the progress of an epidemic, and the type may change in a given locality.

Climate.—Epidemics are more common in hot countries, but no country, however cold, is exempt from invasion.

Season and weather.—Neither cold nor heat, nor any known meteorological condition, has been shown to have any effect in checking or promoting the spread of the disease. Intense outbreaks occur in the hottest and coldest seasons, in good, bad, and changeable weather, apparently indifferently. Each type of weather in turn has been alleged to cause epidemic prevalence, upon the strength of narrow observation confined frequently to one locality and one outbreak. Nothing is definitely known of any relation to atmospheric electricity, or the presence of ozone. It is, however, conceivable that conditions of climate, season, and weather may affect the severity of the epidemic, and especially the mortality from the respiratory complications that usually attend it.

Telluric conditions are apparently without influence. The disease attacks persons of all ages and both sexes, sometimes to the extent of quarter or even half the entire population. In general both incidence and severity of attack are less at ages below 20 years, and less among women than among men; though in some few localities and instances children, and especially school children, suffered more than adults. It would appear that influenza, like diphtheria, may become intensified by *the aggregation* of susceptible persons in a confined atmosphere. Whether it can spread through the air for long *distances* is doubtful. Many instances are on record in which

it was apparently conveyed in that way ? to ships and light-houses, but Parsons has shown that in some of these the isolation was not complete. On the whole, secluded persons and populations suffered least, the incidence being exceptionally heavy upon postal and railway officials, and others whose work brought them most into contact with the public.

Dogs and cats apparently suffer from influenza, and horses are liable to a severe and often fatal disease (termed "pink-eye" from one of its prominent symptoms), which has been regarded as a form of influenza. On several occasions in England and elsewhere epidemics of influenza have been preceded by outbreaks of "pink-eye" But in a Report to the **L G B.** (1893, Klein gives reasons for doubting the transmissibility of influenza to lower animals.

The period of incubation appears to be short, from one to three days. The onset is sudden, with chills, elevation of temperature, and severe pain in the eyes, head, and back, and tenderness of muscles, especially of the legs and back. Three principal forms of the disease are described, with affection respectively of the respiratory or alimentary tracts, or of the nervous system alone. Intense prostration and depression and rapid loss of weight are almost invariable. The symptoms usually abate in three or four days, but complications and sequelæ may protract the duration of illness indefinitely. The breath is in all probability infectious from the first.

The mortality from influenza is usually slight, except among persons already weakened by disease or predisposed to bronchitis or pneumonia. The increased death-rate which follows the appearance of influenza in a district is largely due to deaths attributed to respiratory diseases. The protection, if any, conferred by an attack is slight and evanescent, repeated attacks being common.

In 1892 Pfeiffer discovered a small bacillus in the bronchial mucus of patients suffering from influenza. *It is aërobic, non*-motile and non-resistant. It does

not stain by Gram's method, and grows feebly on artificial media.

The ordinary preventive measures—notification, isolation, and disinfection—have not yet been employed on a large scale against influenza. They would be handicapped by difficulties somewhat similar to those that have been mentioned in connection with measles and whooping cough. Nothing is yet known as to infection by water or food.

Epidemic cerebro-spinal meningitis is characterised clinically by sudden pyrexia accompanied by prostration, with or without a rash, pain in the head and neck, retraction of the head, and often delirium and coma. The symptoms, however, vary widely in different individuals, and in different outbreaks, constituting various types of the disease. Mild and atypical cases may occur in association with epidemics of this disease. The morbid anatomy consists in acute inflammation of the pia-arachnoid of the brain and spinal cord, usually resulting in effusion into the sub-arachnoid space, sometimes of a purulent nature. Little is known as to the etiology. Most epidemics occur in winter or early spring. It is independent of racial or telluric conditions. Some authorities believe that a diplococcus (*D. intracellularis*) is the cause of the disease.

In 1866-67 there occurred a severe epidemic of this disease in Ireland. It was marked by high mortality and the prevalence of hæmorrhagic rashes, and was probably part of an epidemic wave which passed over Europe. In 1905 a severe outbreak with high fatality occurred in New York, which had not suffered from an epidemic of this disease since 1872.

Pneumonia occasionally occurs in an epidemic form, and in many instances has shown distinctly infectious properties without attaining epidemic proportions. Epidemic pneumonia is, with few exceptions

of the "croupous" or "fibrinous" form, but it is not certain that all cases of sporadic croupous pneumonia are due to infection, or that infectious pneumonia is always caused by the same virus. Infectious pneumonia is very often limited to the upper lobe, and often accompanied by pleurisy or empyema. Gastric symptoms, diarrhœa, and jaundice are common, and prostration and cerebral symptoms are frequently intense, out of proportion to the physical signs of pneumonia. The latter may be delayed for days after the onset. The mortality is often high, and usually so in outbreaks limited to a few persons. Epidemics have been described in considerable numbers in England and various other parts of Europe during the last two centuries. Although more frequent in temperate climates, many are recorded in the West Indies, Mexico, Peru, and India. Nearly all occur in winter or spring, and the seasonal curve of epidemic prevalence coincides pretty closely with that of pneumonia mortality, which has its maximum in December, and is high from November to April. Hence the prevalence of pneumonia—epidemic or otherwise—is associated with the colder months, and a closer analysis shows that in each climate the greatest prevalence of pneumonia occurs at the season of most rapid and sudden changes of temperature, be it winter or spring (*Hirsch*), and there is evidence tending to show that the prevalence varies in some measure with the intensity of the changes of temperature. Epidemics occurring at unusual seasons have often been associated with unusual meteorological conditions of the same kind.

The popular belief in "chill" as an exciting cause of pneumonia cannot be entertained as regards infectious pneumonia, in spite of the strength of the evidence which connects pneumonia outbreaks with the weather conditions in which "chill" is believed to be most liable to occur. Exposure to sudden

changes of temperature or extreme cold may increase the activity of infection or the susceptibility of the individual, but nothing more. If, however, there is a non-infectious and non-specific croupous pneumonia, the question of "chill" may be argued upon different lines. It is said that croupous pneumonia has been produced by injecting irritants into the lungs of dogs, by mechanical injury to lung tissue, by experimentally injuring parts of the nervous system, and by various other mechanical means, which may be admitted as establishing some sort of *prima facie* possibility of like effect from sudden change of temperature, especially as the whole mortality attributed to pneumonia (and not merely that part which is already recognised as due to an infectious form of the disease) reaches its maximum at times of greatest liability to "chill." On the other hand, attempts to produce pneumonia by exposing animals to sudden alternations of temperature have uniformly ended in failure, and even traumatic pneumonia may conceivably be dependent upon the co-operation of specific microbes occidentally gaining access to the injured tissue.

There are now on record many instances of outbreaks of pneumonia which remain limited to a single household or a small circle, but in which nevertheless the evidence points strongly to infection.

Nothing conclusive has been established as regards the influence of rainfall or telluric conditions upon pneumonia, although it has been asserted that absence of rain (dry cold) and low level of subsoil water are favourable conditions.

Males are far more liable to pneumonia than females, but the attacks are usually less severe and fatal. In the Middlesbrough epidemic of 1888 Ballard found that the female case mortality only exceeded the male at ages above sixty-five years. Both the liability to attack and the average case mortality increase greatly as age advances. In childhood and old age the mortality is highest, and urban death-rates are usually in excess of rural.

All depressing conditions predispose to attack *during* epidemic prevalence, among them fatigue, *anxiety*, poverty, and debility from any cause.

Insanitary conditions, especially filth, overcrowding, and want of ventilation, act apparently as powerful but not indispensable predisposing causes. Effluvia from graveyards have also been held responsible for outbreaks. Repeated outbreaks have sometimes been observed in the same buildings, especially barracks and prisons. In many extensive epidemics it has been found that those streets or houses suffered most which were in the worst sanitary condition, and outbreaks in barracks, prisons, and ships have usually been attributed to the same causes. Such conditions must not be regarded as more than predisposing causes in any case, and in many instances—notably in several of the small outbreaks of infectious pneumonia limited to one household—they are conspicuously absent. Negroes are especially susceptible to pneumonia, even in their native climate.

Friedlander's oval, capsulated *pneumo-bacillus* is found in large numbers in the affected lungs, and in the blood and sputa in croupous pneumonia (but not in acute catarrhal pneumonia or septic pneumonias). It was found in abundance in the substance of the floors and ceilings of rooms in a prison at Amberg where repeated outbreaks of pneumonia had occurred for many years (*Emmerich*). Pneumonia has been produced in rabbits by the injection of cultivations; on the other hand these results have been disputed, and the true pathogenic microbe asserted to be Fränkel's small, oval, capsulated *diplococcus*, which is non-motile, non liquefying and aerobic. It is difficult to cultivate, and rapidly loses virulence. It is stained by Gram's method. It is by far the most frequently present organism in croupous pneumonia, and may be present in other diseases, suppuration, otitis media, ulcerative endocarditis, and meningitis.

The widespread and fatal epidemic of pneumonia

that occurred at Middlesbrough in 1888 was investigated by Ballard. Out of 1,633 cases in a population of 97,000, 369 ended fatally, the case mortality being 21 per cent. The poorer classes suffered more than the wealthy, and cases were exceptionally numerous and severe in the workhouse, where the drainage was very faulty. The workhouse children suffered six times, but adults only one and a half times, as much as the corresponding class outside. Exposure and fatigue seem to have acted as predisposing causes, and many apparent instances were recorded of direct infection from contact with a sick person. The progress of the epidemic seemed to be arrested by heavy rains, and to be most rapid during rainless periods. Klein found neither Friedländer's nor Fränkel's organisms, but large numbers of short bacilli, which he named *Bacillus pneumoniæ.* Inoculation of human lung-juice or of cultivations of the bacillus into mice caused an acute disease, the chief and constant lesion of which was pneumonia; further inoculations from such mice imparted the same disease to other mice. Samples of bacon were purchased in the infected districts, and it was found that of mice fed upon this bacon a large proportion became ill, with the same symptoms as those mentioned above. The *Bacillus pneumoniæ* was recoverable by cultivation from their tissues, and by inoculation the disease could be transferred to other mice. Whether the bacon had or had not become infected by human cases of pneumonia is not clear, but it may be suspected that the disease was capable of being spread by means of infected food.

The incubation appears to be short, frequently about five to seven days. The onset is sudden, and usually marked by rigors and severe constitutional symptoms, the signs of pneumonia being often delayed for three or four days. The fifth day is often fatal;

and, on the other hand, crisis often occurs on or about the fifth, seventh, or ninth day, but sometimes the course, even in non-fatal cases, is severe and protracted, the symptoms being of a "typhoid" character.

Both the breath and the sputa may be assumed to be infective.

The mortality varies considerably, but is usually high, especially in elderly persons and in the outbreaks limited to a narrow circle. In some epidemics, however, it has been as low as 5 per cent.

Epidemics of pneumonia often occur coincidently with outbreaks of other diseases, and especially enteric fever. Pneumonia is a common complication or sequela of enteric fever, and it has been suggested that an invasion of the system by the enteric poison may have its sole manifestation in pneumonia, the usual intestinal lesions being slight or absent.

Tuberculosis is a specific and infective disease common to man and the lower animals. The principal form in which it affects man is pulmonary tuberculosis or phthisis, but all parts of the body are liable to be invaded. The mortality due to tuberculosis is enormous, but does not admit of exact statement, owing to imperfections of diagnosis, nomenclature, and classification. Pulmonary phthisis may be accepted as a fairly well defined division, although it undoubtedly includes a certain proportion of non tubercular destructive diseases of the lungs. Tubercular meningitis is not sufficiently distinguished in death-returns from other diseases that are attended with somewhat similar symptoms, and "tabes mesenterica," which is classed as a tubercular disease, includes a large annual number of deaths among children from wasting diseases, of which no exact diagnosis has been made.

Phthisis, "consumption," or pulmonary tuberculosis *is largely* dependent upon known and

remediable conditions, and improved hygiene has led to a steady decline in mortality from this cause. Nevertheless it still ranks among the most fatal diseases, especially during adult life, and as recently as the decennial period 1894-1903 it was the recorded cause of nearly one-tenth of the whole mortality in England, and of about forty per cent. of the deaths at ages between twenty and forty-five.

Its geographical distribution is almost world-wide. Neither hot nor cold climates are exempt, but humidity, especially if the daily range of temperature is high, is frequently associated with prevalence of phthisis. Cold, and especially Arctic countries, suffer comparatively little as a rule, and the exceptions are mostly explicable by social conditions involving overcrowding and want of ventilation. Other things being equal, elevated and mountainous regions are less affected than lowlands, owing, it is believed, to the dryness and purity of the air and soil, and the fuller and deeper respiratory movements. A general relation between dampness of soil and prevalence of phthisis has been affirmed by Buchanan* in England and Bowditch in America. Considerable and early reduction in phthisis mortality has, in many instances, followed artificial drainage of damp localities. In Ely the reduction was 47 per cent., and in Salisbury 49 per cent., but at Ashby-de-la-Zouch, Alnwick, and Carlisle, Buchanan

* The mortality statistics of the decennium 1851-60, for Surrey, Kent, and Sussex, showed that there was less phthisis among populations living on pervious soil than among those living on impervious soils; less on high-lying pervious soils than on low-lying pervious soils; less on sloping impervious soils than on flat impervious soils. Buchanan also found a general agreement in phthisis mortality between districts that have *common* geological and topographical features of a nature to affect the *water-holding* quality of the soil—an agreement not observed in districts *differently* circumstanced in such respects; and further, a general *parallelism* between the degree of wetness of soil and the degree of *phthisis incidence.*

found an increase coincident with drainage of the towns, and the same was observed at Danzig and elsewhere. In several of these cases, however, the local conditions were such that the drainage works did not materially dry the soil. It is stated by many authorities that phthisis does not occur in marshy regions which are "malarious," and Kelly found that the phthisis mortality is greater upon the drier soil.

Towns suffer more than rural districts, and there is a close relation between density of population and phthisis mortality, due to the co-operation of several causes, chief among which are overcrowding, poverty, and stagnation and impurity of air. The heaviest incidence is upon the poorer classes, and especially those living in narrow streets, alleys and courts, and in back-to-back houses. Conditions inside the houses such as overcrowding and want of ventilation are even more potent, and repeated experience in barracks, workhouses, prisons, and other public institutions, as well as in ships, has shown that with improved ventilation and ampler air-space the mortality from phthisis is greatly reduced. Among nomadic races the disease is rare.

Many trades have a tendency to induce phthisis, and especially those industries which are carried on in overcrowded, hot, moist workrooms, or which charge the air with mineral or organic dust of an irritating kind. Exposure to rapid alternations of temperature is very injurious. Greenhow attached much importance to a stooping or cramped posture at work, as predisposing to phthisis.

Among other predisposing conditions, intemperance and debilitating causes of all kinds are important. Brouardel considers that "alcoholism is the most potent factor in propagating tuberculosis," and he quotes Baudran as showing that the deaths from *tuberculosis per 10,000* rise in proportion to the annual

consumption of litres of alcohol per head. In this country the Registrar-General has shown that more than one quarter of the deaths of innkeepers and their servants in London result from phthisis; more than one-third of the deaths of public-house servants, barmen, and potmen in London are due to phthisis; and the mortality from this disease among London innkeepers and their servants is more than twice as great as that among all occupied males, and the mortality amongst the servants alone is more than three times as great. No doubt some of this mortality is due to inhalation of tuberculous dust from dried sputum. Then there is the lowering effect of previous disease. Attacks of pleurisy, bronchitis, or pneumonia increase the liability to phthisis, and so, too, do many forms of specific fevers (notably measles, whooping cough, and enteric fever), and other diseases, for example diabetes and insanity. The low phthisis mortality among fishermen, agricultural labourers, and others following essentially out-door employments, seems to indicate that exposure to weather has been overrated as a predisposing cause, for this condition in a great measure implies abundance of fresh air.

Rightly or wrongly, a large but decreasing number of deaths of young children under five years of age is attributed to phthisis. The annual mortality per million living at ages under five years was 968 in 1861-70, 767 in 1871-80, and 536 in 1881-90. From five to ten years the mortality is at a minimum, and then rises steadily to its maximum at ages between 35 and 45, after which it declines again as age advances.

The influence of sex is very marked, but is to be explained for the most part by differences of surroundings rather than by variation in natural susceptibility. In proportion to their numbers males suffer a higher phthisis mortality than females at all ages except

between 5 and 25 years. While the mortality is decreasing rapidly in both sexes, the decline among females is greater than that among males.

PHTHISIS MORTALITY IN ENGLAND AND WALES, 1851-1900 (PER 1,000 LIVING).

Decennia.	Males.	Females.	Total.
1851-60 . . .	2·6	2·8	2·7
1861-70 . . .	2·5	2·5	2·5
1871-80 . . .	2·2	2·0	2·1
1881-90 . . .	1·8	1·6	1·7
1891-1900 . . .	1·5	1·2	1·3

In London also there has been a steady decline. In 1904 the phthisis death-rate was 1·62 per 1,000, having fallen from 1·90, 1·79, 1·71, and 1·64 respectively in the four preceding years. In 1904, when the phthisis death-rate was 1·62 for the whole of London, it was as low as 0·83 in Hampstead and as high as 2·18 in Shoreditch, 2·36 in Southwark, 2·39 in Finsbury, and 2·86 in Holborn. The steady decline in the incidence of the disease may also be stated as follows: that whereas in the ten years 1894-1903 the average number of deaths from phthisis in London was 8,097, the number for 1904 was 7,738.

No race is exempt, but among Jews phthisis appears to be rare, and this comparative immunity has been partly attributed to the care that is taken in the selection of animals slaughtered for food. Natives of hot countries migrating to cold, damp climates are very prone to phthisis.

The tendency to phthisis may be inherited, in the form of constitutional weakness, or of a narrow, contracted chest. Whether heredity can do more than strongly predispose to the disease is very doubtful. Tubercle has in rare instances been found in children *within a few days of* birth, and even in the fœtus.

Various observers have obtained evidence of parental phthisis in from 15 to 30 per cent. of the cases coming under their notice, but this proportion is scarcely sufficient to establish the proof of heredity. A family history of phthisis is obtainable in 50 per cent. of hospital cases of this nature.

Deaths from phthisis are most frequent in spring (March and April), and least so in autumn (September and October). The seasonal curve of mortality is therefore later than in the ordinary respiratory diseases, but it serves to indicate seasonal conditions accelerating death rather than those primarily inducing a disease of long and uncertain course.

Bacteriology.—The pathogenic microbe of tuberculosis, discovered by Koch in 1882, is a motionless, slender, beaded bacillus which, under suitable conditions, forms spores. The bacilli are very slow in growth and multiplication, taking one, two, or even three weeks to form a colony on artificial media, and they require for that purpose a somewhat high temperature, which must further be maintained within narrow limits, about 37° to 39° C. A peculiarity that distinguishes them from all other bacilli except those of leprosy and syphilis is that after staining with fuchsin they are not decolorised by nitric acid (Ziehl-Neelsen method). They are therefore termed *acid-fast.* There are in addition to the tubercle bacillus a group of acid-fast bacilli allied to the streptothrix family. They possess, however, characters which differentiate them from the tubercle-bacillus. These latter bacilli are found in all tuberculous lesions, both in man and the lower animals. They have been found also in the blood, and in certain secretions (milk), and they abound in phthisical sputa. Cultivations if inoculated or injected into susceptible animals reproduce the disease. The bacilli are readily destroyed by many chemical or thermic means, and by prolonged

exposure to sunlight, but the spores are tenacious of vitality.

Tuberculosis can be acquired by inoculation, inhalation, or swallowing. Inoculation is comparatively rare, and usually causes a local lesion only. Inhalation would seem to be by far the most common source of infection. The bacilli, or rather their spores, are found in air-borne dust, especially in rooms inhabited by phthisical persons. The daily sputa of a single patient may contain many millions of bacilli, and drying for months will not destroy their virulence. The prevalence of the pulmonary form of tuberculosis, and its close relation to air-conditions, are not without significance, as pointing to air-borne infection. A further analogy to the ordinary infectious diseases is to be found in the strong evidence which has been adduced by Ransome and others to show that tuberculosis attaches itself to particular small localities ("Tuberculous Infective Areas"), houses, and even rooms. The bacilli have been found not only in the air and dust, but in the walls of rooms occupied by phthisical persons. Coates investigated this point in houses in Manchester, in 1900, with the following results:—

(1) Dirty houses in which a consumptive patient is living who takes no precautions to dispose of his expectoration, but spits freely upon the floor and into his pocket handkerchief: In 66.6 per cent. of these houses virulent tubercle bacilli were found, showing the large amount of dangerous infective material present in an infected house.

(2) Clean houses in which a patient is living who is not sufficiently careful as to the disposal of his sputa: In 50 per cent. of these instances the bacillus was found. It is evident that ordinary household cleanliness alone is insufficient to prevent the accumulation of infective material in rooms occupied by a *consumptive.*

(3) Very dirty houses in which there had been no case of consumption for some years: In this class of house no tubercle bacilli were present, showing that virulent dust found in classes 1 and 2 must have been due to the presence of the consumptive patient.

Niven examined the records of 5,000 deaths from this cause in Oldham, and found that whereas the mathematical probability was that 68 houses would be invaded twice, and 7·6 three times, the actual numbers were 274 and 24 respectively. Many other workers have confirmed this. The endemic areas occur chiefly in the worst parts of towns, when the predisposing conditions already referred to exist in maximum intensity. Whenever tuberculous sputum is allowed to dry the risks are therefore great that the dust so produced may be inhaled in a virulent form, and lodging at one or more points may set up varying degrees of tuberculosis. This broad fact is based upon experimental and clinical evidence. Tuberculosis has been produced experimentally in animals in this way, and there is clinically the overwhelming frequency of tuberculosis of the lungs among men exposed to this form of infection. But Koch, Flügge, and others have shown that not only is sputum a source of infection when dried and pulverised, but also when disseminated by coughing, shouting, etc., in the form of minute moist particles of spray.* Koch exposed rabbits, guinea-pigs, rats, and mice to an infected spray for half an hour on three successive days, and produced tuberculosis in every animal. Heymann found that such spray particles from human beings inoculated into guinea-pigs produced tuberculosis. Most of the droplets are large

* Mervyn Gordon in this country has confirmed these results by applying a streptococcus test for saliva (in which secretion 10 millions *streptococci* per c.c. may commonly occur). He finds that during loud *speaking* bacteria may be projected by means of salivary spray a distance *of 40 ft.*

and settle rapidly, but some may remain suspended in the air for more than an hour, retaining, of course, their virulent properties. Heymann found the duration of life of the bacilli in these droplets was eighteen days in the dark, and three days when exposed to light. Under ordinary circumstances and an absence of draughts, the zone of danger from a coughing consumptive extends to a distance of about three feet. It must be remembered that the tubercle bacilli in the moist particles of "cough-spray" are probably of higher virulence than those in dried sputum dust, and therefore it seems reasonable to suppose that the cough spray is one of the most ready modes of infection. The degree of infectivity of phthisis is not, however, a very high one. It is a true infective disease, but only a sub-infectious one.

There is still much doubt as to the frequency of direct infection from person to person, but none as to its occasional occurrence, or as to the fact that almost all persons must frequently inhale and swallow living tubercle bacilli. Fortunately the microbe is very slow in its development, and exacting in its requirements as to temperature and surroundings, so that the vast majority that gain entrance to the respiratory tract are expelled or perish. The long duration of the disease, the wide and general diffusion of the virus, the paramount importance of predisposing conditions, and the difficulty of infection in their absence, all combine to render obscure the time and source of infection. Statistics are inconclusive even in regard to transmission of phthisis between husband and wife.

We have previously referred to the conveyance of tuberculosis by milk and meat (*see* page 106). The risk of contracting the disease by consuming tuberculous milk and meat is undoubted, but the disease *does not appear to* be widely spread by these means.

As regards milk, all danger of infection may be obviated by boiling, and prevented by using milk from tubercle-free herds only (tested by *tuberculin*, which is a glycerine extract of dried residue of young cultures of the tubercle bacillus). The cooking to which meat is subjected is frequently insufficient to destroy bacilli that may be present in the deeper parts.

The heavy mortality among children from "tabes mesenterica" (*tubercular peritonitis*) and *tubercular meningitis* is urged as a confirmation of the extreme prevalence of tubercular disease, but it is probable that both of these terms are employed in the loosest way in making out certificates, and it would not be safe to place much reliance upon the tubercular nature of the majority of the cases so certified. The former disease (*tubercular peritonitis*) has been attributed to the consumption by children of tuberculous milk. Still, however, has shown that the commonest channel of infection in tuberculosis of children is through the lung, and that infection though the intestine, as would occur if it were milk-borne, is less common in infancy than in later childhood. There is, however, substantial evidence that tuberculous milk can and does set up some form of tuberculosis (bovine or human) in the bodies of persons consuming it.

Tuberculosis often ends in recovery. The records of long series of autopsies of persons who have died of other diseases show that traces of cured phthisis are found in a proportion variously estimated as 25 per cent. and upwards. It is not in any degree protective against a further attack.

Bovine and Human Tuberculosis.—Since the discovery by Koch in 1882 of the tubercle bacillus, it has generally been held that tuberculosis in man and animal is one and the same disease. Villemin (1865) was the first to maintain

this identity on the results of inoculation of bovine and human tubercular matter into small animals Chauveau (1868) carried out similar experiments upon cattle. Both workers were successful in transmitting the disease, which produced similar effects in the inoculated animals. Many other workers have obtained like results, which were more or less uniformly in support of the identity of bovine and human tuberculosis. The Royal Commission on Tuberculosis, 1895, said: "We regard the disease as being the same disease in man and the food animals, no matter though there are differences in the one and the other in their manifestations of the disease; and we consider the bacilli of tubercle to form an integral part of the disease in each, and (whatever be its origin) to be transmissible from man to animals and from animals to animals. Of such transmission there exists a quantity of evidence, altogether conclusive, derived from experiment."

It was, however, conceded on all hands that tuberculosis was a more virulent disease in animals than in man, and that the bacillus in the two species differed in morphological, biological, and pathological properties. In 1901, at the London Congress on Tuberculosis, however, Koch expressed the opinion that, "human tuberculosis differs from bovine, and cannot be transmitted to cattle," and that bovine tuberculosis was scarcely, if at all, transmissible to man. On the same occasion counter-evidence was produced by MacFadyean, Ravenel, Crookshank, and many others.

Koch based his opinion upon the negative results which followed the feeding of six cows with human tubercular sputum, making 4 others inhale human tubercle bacilli and otherwise infecting 9 more. None of the 19 cattle suffered, and no tuberculosis was found in their body tissues post-mortem. *When, however, such cattle* were infected with bovine disease

they contracted it. Swine were also fed in a similar way, with like results.

In 1902 Koch again emphasised the comparative rarity of primary intestinal tuberculosis in the human being, and the local, as distinguished from the general, infective nature of accidental bovine inoculation of man (*tuberculosis verrucosa cutis*). In isolated cases the nearest lymph glands might become affected, but the disease remained nevertheless a local one. Koch further expressed the view that if bovine tuberculosis was transmissible to man by means of the milk of cows with tuberculous udders, it would be reasonable to suppose that "groups of illnesses" would occur, in a manner analogous to other infective diseases, though the circumstances would differ owing to the different length of the incubation periods. By way of illustrating the non-infectivity of bovine tubercle bacilli conveyed by milk, Koch points out (*a*) that bovine tubercle bacilli must be taken into the human system very frequently, as 1 to 2 per cent. of all milch cows suffer from tuberculous udders; (*b*) that in addition to being drunk in considerable quantity and for long periods, such milk is also widely distributed; (*c*) that domestic sterilisation of milk does not occur to any appreciable extent; (*d*) that the same may be said of the large dairies; and finally (*e*) that if milk under such circumstances is dangerous, the butter derived from it will also be dangerous. For these reasons he maintained that any resulting disease must be widespread. Yet Koch has found "instead of the countless cases," which we ought to expect, "two groups of illnesses and 28 isolated cases of illness." On examination he finds most of these recorded cases not free from objection. To carry conviction as to milk-borne tuberculosis, Koch maintains that the following conditions must be fulfilled:—(i.) Certain proof of tubercle in the person affected; (ii.) exclusion of other sources of infection; (iii.) the condition of all the consumers of the suspected milk; (iv.) the exact source of the suspected milk, particularly in respect to the disease of the udder of the cow yielding the milk. Finally, he concludes that all that can be said at present is that the injurious effects of milk infected with bovine tuberculosis and its products are not proven.

As a result of the wide differences of opinion revealed by the pronouncement of Koch's views, special Commissions of Inquiry were instituted in Germany, Great Britain, and other countries, to

addition to the individual research work carried out by many workers.

Kossel, Weber, and Heuss, who carried out a comparative research upon tubercle bacilli of different origins for the German Imperial Health Office, made a number of experiments on calves by injecting some forty different strains of human bacilli and fifteen strains from cows, fowls, and swine. They conclude (1904) that in a preponderating number of cases of human tuberculosis bacilli occur which were found distinguishable from the bovine bacilli of *perlsucht* morphologically, culturally, and in pathogenic properties, but that exceptionally in man tubercle bacilli occur which cannot be distinguished. They hold that the possibility of infection in man under certain circumstances by milk from tuberculous udders is proved. They found that generalized tuberculosis was produced in animals by injecting strains of tubercle bacilli obtained from tuberculous diseases in children.

A Royal Commission was also appointed in this country, and in an interim report (1904) said

"We have very carefully compared the disease set up in the bovine animal by material of human origin with that set up in the bovine animal by material of bovine origin, and so far we have found the one, both in its broad general features and in its finer histological details, to be identical with the other. We have so far failed to discover any character by which we could distinguish the one from the other."

Rabies (Hydrophobia).—There are two chief forms, "furious" and "paralytic" The former is the commoner in dogs. The disease is comparatively rare in man, but is one of interest and importance from the point of view of preventive medicine. There were 761 deaths from hydrophobia in England and Wales between 1866 and 1885, Lancashire, London, *the West Riding*, and Cheshire being the principal

"foci," whence the rest of the country was subjected to repeated inroads. There were no deaths due to rabies in this country during the six years 1899-1904, except two in 1902. In the decennium ended 1890 there were 29 deaths on an average yearly.

Hydrophobia causes most deaths at ages between five and fifteen years; more among males than females; and more in late summer and autumn than at other seasons (*Longstaff*).

The disease is imparted to man by the bite of rabid dogs; or more rarely of rabid cats, foxes, or wolves. The ordinary incubation period is six weeks. It is stated to have been as short as one week in children bitten about the face. The disease almost invariably ends in death within a few days. It is not known to have been transmitted from one human being to another. Bites about the face are more deadly than others, and in such cases the incubation is short. The danger is less when the part bitten is protected by clothing. Taking only cases of bites by animals proved beyond doubt to be rabid (the proof being the occurrence of a genuine case of rabies in some person or animal bitten by them or inoculated from them), hydrophobia manifests itself in about 15 per cent. of the persons bitten. By means to be described presently, this mortality may be greatly reduced, and by other preventive measures rabies can be, and has been, stamped out altogether.

Pasteur discovered that the virus, though absent from the blood, is present in the spinal cord of rabid animals as well as in the saliva, and that a portion of the spinal cord of a rabid animal (or human being dead from hydrophobia), inoculated beneath the dura mater of a rabbit, imparts the disease with certainty. This alone would be important as a *certain* means of diagnosis; but Pasteur further demonstrated that the virulent cord gradually loses its

virulence if kept in perfectly dry air, and that this attenuation afforded a means of curative or protective inoculation He inoculated at short intervals with successively more and more virulent material, commencing with very attenuated virus (14 days old), until at last fresh cord was employed. It is surmised that the protection is due to a chemical substance, and not to any real attenuation of the microbe. However this may be, the result of the course of inoculations—so far from causing rabies, as a single inoculation with fresh rabic cord would do—is to render dogs insusceptible to rabies. The same treatment is now extensively practised in regard to persons bitten by rabid animals; and the mortality among such, under early treatment, is no longer 15, but a fraction of 1 per cent. In the decennium 1893 1902 an average of 1,450 persons were treated annually at the Pasteur Institute in Paris and the rate of mortality was 0 32 per 1,000

The microbe has not been isolated with any certainty, although both micrococci and bacilli have been found in the rabic cord.

Rabies can be stamped out by muzzling all dogs for a sufficient length of time. This was done in Sweden many years ago, and the country remains free from rabies. Less isolated countries are subject to constant new importations of the disease across the frontiers, but the success of repressive measures has been very great. Thus hydrophobia, though formerly prevalent, has been unknown in Berlin since 1874, and the Prussian provinces are practically free except on the eastern (Russian) frontier.

In England several local attempts were made in the same direction, but none upon a large scale until 1890, when it was made compulsory for a time throughout Lancashire, Cheshire, the West Riding, and London, and was followed by the cessation of

rabies. In London muzzling was adopted in 1885, and speedily put an end to the prevalence of rabies. The *Rabies Order* of 1892, issued by the Board of Agriculture, enables county authorities to make regulations for muzzling and other preventive measures.

Glanders or **farcy,** as affecting man, was only described during the last century. Although in isolated instances it has been transmitted from one human being to another, it is practically always acquired from the horse. The virus does not appear to be capable of aërial transmission, except, perhaps, for very short ranges, and nothing is established as regards convection by water or milk. Inoculation is the almost invariable mode of infection so far as man is concerned; but it is probable that this may sometimes occur without abrasion of skin or mucous membrane. Among animals the disease spreads rapidly. It is very rare in man, but attended with an extremely high mortality, which is stated to be not less than 50 per cent. in chronic cases, and not far from 100 per cent. in the acute variety. The usual incubation ranges from three to eight days, and is shortest in acute cases. For obvious reasons, men are much more liable to glanders than women or children. The disease affects the nasal and respiratory mucous membranes, and also the lymphatic glands. When the latter are attacked first, the disease is termed *farcy*.

Anthrax affects man in two forms, external and internal. External anthrax, or "malignant pustule," has its usual seat about the face or neck, and is no doubt due to inoculation. The first local manifestation is the appearance of a papule or vesicle, which develops in the course of a few days into an inflamed indurated mass, with a central black slough. The border may be fringed with vesicles or inflamed. The surrounding tissues and the lymphatic glands are swollen and indurated. The disease may remain localised, and end in resolution, or at most in suppuration. Usually, however, constitutional symptoms attend its course, and general infection may follow. Occasionally malignant pustule supervenes upon internal anthrax. Internal anthrax appears to be due to inhalation

swallowing of the poison. After a very variable incubation period, ranging perhaps from two to twelve days, the early symptoms are chills, weariness, depression, restlessness, and a feeling of constriction in the chest. This prodromal stage may last only a few hours, but more usually two to six days, and then graver symptoms set in suddenly. The prostration becomes extreme; pulse and respiration are rapid. The temperature is somewhat elevated, but always liable to sudden remissions, accompanied by perspiration. The patient may die from heart-failure, or brain symptoms may become prominent, or pneumonia or diarrhœa may supervene. Remissions may occur. The mortality is high, but recovery may happen even in serious cases The protection derived from an attack is very slight, if any.

Anthrax received the name of "wool-sorters' disease" from its prevalence among men employed in sorting infected foreign wool and hair. Tanners, butchers, and persons engaged in handling raw hides or horse-hair are liable to malignant pustule.

Anthrax attacks sheep, goats, pigs, cattle, and horses, and may be communicated to mice, guinea-pigs, and many other animals. As in man, the disease may be either localised or constitutional, and in the latter variety enlargement of the spleen is so prominent a characteristic that anthrax is known as "splenic fever." A field may become infected with anthrax, and healthy animals turned into it after the lapse of months, or even years, may acquire the disease. The infection is probably imparted to the superficial layers of the soil by the blood or secretions of affected animals, in which the resistant spores form. Pasteur suggested that the spores from buried carcases are brought to the surface by earth-worms, but Klein has found that spores are not formed under such conditions, and that within a week all bacilli and all

infectivity have been destroyed by putrefaction, if the carcase is buried intact. Other sources of infection of animals are the use of infected dust or other trade refuse as manure, and drinking from streams receiving infected trade effluents.

Although exact evidence is wanting, it may be assumed that anthrax can be acquired by eating the flesh of diseased animals. The usual modes of infection in man are by inoculation and inhalation, and it has been suggested that the poison may be carried by flies and other insects.

Bacteriology.—The pathogenic organism is the *Bacillus anthracis*, which forms spores when exposed to air. The bacillus, which grows readily on ordinary media, is square-ended, 1 μ broad and 4-5 long, sometimes in filaments; aërobic, non-motile, liquefying; chiefly occurring in spleen and blood stream, and readily destroyed by heat or other disinfecting agencies, though the spores are extremely resistant. It has been found that animals can be infected by inhaling or swallowing the spores, but not by the bacilli unless there is some abrasion such as to allow practically of inoculation. Bacilli are destroyed by the gastric juice, spores are not. A further marked difference between bacilli and spores is shown by the results of inoculation (*Klein*). The former cause a slight and localised form of the disease, the latter a severe constitutional malady, which is usually fatal. Thus, the fresh blood of a mouse dead of anthrax contains bacilli only, but upon exposure to air, or artificial cultivation, spores are readily formed. Inoculation of the fresh blood into sheep is followed by slight local anthrax, but if blood containing spo[res] is used a fatal attack ensues. Moreover, if [two] animals of the same species are inoculated, one [with] *spores* of a broth culture and the other with bacilli [of] a gelatine culture, the blood bacilli of the latter

be more attenuated than the former. But apart from this, anthrax virus varies in intensity according to the animal from which it is taken. Comparing the results of inoculation with virus from mice, guinea-pigs, sheep, and cattle, it is found that virulence increases in the order stated, mouse anthrax being the least and cattle anthrax the most potent.

Martin has shown that the *Bacillus anthracis* produces albumoses, which in turn yield toxins much more virulent than themselves. Sclavo of Siena has prepared an anti-anthrax serum from which excellent results have been obtained, reducing case mortality from 24 to 6 per cent. The animal used for immunisation is the ass, which is inoculated with slowly increasing doses of virulent cultures of the anthrax bacillus. Blood is drawn from the left jugular vein, and after clotting the serum is decanted and ether added to the extent of 3 per cent. of the whole bulk. The serum is then bottled with antiseptic precautions in 10 c.c. tubes.

In external anthrax early excision is of the greatest importance, and usually results in recovery.

Cases of anthrax in horses, cattle, sheep, pigs, etc., are dealt with under the Anthrax Order of 1899, issued by the Board of Agriculture. The owner reports the outbreak to the inspector specially appointed for the purpose by the local authority. It is the inspector's duty to inform the **M.O.H.** and to direct precautionary measures as to isolation, disinfection, and destruction of the carcase, as prescribed in the Order.

Tetanus.—Tetanus occurs in man and horses most commonly, though it may affect other animals. There is usually a wound, often an insignificant one, which may occur in any part of the body, but is nearly always on one or other of the limbs. It is not the *locality of the* wound nor its size that affects the

disease. Wounds which are jagged, and occurring in absorptive tissues, are those most fitted to allow the entrance of the bacillus. The wound forms a local manufactory, so to speak, of the bacillus and its secreted poisons; the bacillus remains in the wound, but the toxins may pass throughout the body, and are especially absorbed by the cells of the central nervous system. Suppuration generally occurs in the wound. After a few days or, it may be, as much as a fortnight, when the primary wound may be almost forgotten, general symptoms occur. Their appearance is often the first sign of the disease. Stiffness of the neck and facial muscles, including the muscles of the jaw, is the most prominent sign. This is rapidly followed by spasms and local convulsions, which, when affecting the respiratory or alimentary tract, may cause a fatal result. Fever and increased rate of pulse and respiration are further signs of the disease becoming general. After death, which results in the majority of cases, there is very little to show the cause of fatality. The wound is observable, and patches of congestion may be found on different parts of the nervous system, particularly the medulla (grey matter), pons, and even cerebellum. The experience of the Pasteur Institute tends to support the theory that tetanus is a "nervous" disease, more or less allied to rabies, and is best treated by intra-cerebral injection of antitoxin, which then has an opportunity of opposing the toxins at their favourite site. The toxins diffuse throughout the tissues of the body, but particularly affect the spinal cord. The long incubation period indicates that the toxins are probably produced by a ferment which is a most powerful poison.

Tetanus bacilli spores have been found in considerable quantities in the dust of dry jute fibre (*Andrewes*), and various cases are on record where the disease has been contracted in jute mills. Legge

attributes the presence of the bacilli to the soil in which the jute is grown in Bengal.

In the wound the bacillus is present in large numbers, but mixed up with a great variety of suppurative bacteria and extraneous organisms. It is a straight short rod with rounded ends, occurring singly or in pairs or threads, and slightly motile. Flagella may be demonstrated (lateral and terminal). Branching also has been described. Indeed, it would appear that, like the bacillus of tubercle, this organism has various polymorphic forms. A large round spore occurs at one or other pole of the bacillus ("drumstick" appearance). The spores are very resistant. The bacillus is an anaërobe, and grows at blood heat. In some soils it is common, and infection has frequently been derived from dust in jute factories, etc. The disease is more common in hot countries than in temperate climates, and can frequently be induced in animals experimentally, by inoculation of a little garden earth, manure, refuse, or soil.

CHAPTER XV.

Tropical Diseases.

In this chapter will be considered briefly some of the chief tropical diseases. Many diseases, such as pneumonia, diarrhœa, relapsing fever, typhus and typhoid, occur of course in sub-tropical and tropical countries; but such diseases as cholera, yellow fever, plague, malaria, and leprosy may rightly be considered as more correctly "tropical" diseases.

Asiatic cholera has its endemic area in certain parts of India, including the delta of the Ganges. The first great epidemic in India occurred in 1817. At irregular intervals it spreads in epidemic or pandemic form over a great part of the world. It follows the lines of traffic by land or water, but no reason has been found for the apparently capricious selection of some routes and omission of others. The invasion of each new country along its line of march is almost invariably traceable to infection through some point of communication with a country already attacked. In temperate climates the outbreak often subsides or disappears in winter, but frequently reappears with the warm weather in the late spring or early summer; and may even recur again in the third year, apparently without fresh introduction.

Cholera gained a firm footing in England on four occasions, viz. 1831-2, 1848-9, 1853-4, and 1865-6, the epidemic extension from India having occupied respectively *five*, *two*, *one*, and *two* years in transit.

In 1831 infection was carried to Sunderland and Newcastle, *from Baltic* ports, in October, and in the course of the next year caused great mortality throughout the kingdom. The system of registration of deaths was not then in operation, but

according to Hirsch, the total mortality in England was 30,924. In 1848 Hull was infected from Hamburg early in October, and the disease at once spread. Only 988 deaths were recorded in England from October to March, but the epidemic made rapid progress in the summer, and before its final disappearance in December, 1849, it had caused 53,293 deaths, besides a heavy diarrhœa mortality, part of which may be supposed to have been due to cholera. In 1853-4 the invasion was again from Germany, London being attacked in August The outbreak continued through the winter, especially in the north, became more active in July, 1854, and overran the country, causing during the year 20,097 deaths in England and Wales. The 1865-6 epidemic was milder, but still resulted in 14,378 deaths.

On several other occasions the disease has invaded Europe, but failed to reach England, notably in 1871-4 and 1884 7. In 1892 it again spread to many parts of Western Europe, notably Hamburg, but apart from imported cases none appeared in England until September, 1893, when a few occurred at Grimsby, Hull, and elsewhere. Since then only small isolated outbreaks have occurred in this country.

Climate, season, and temperature.—Heat is a predisposing condition of great importance, but cold does not necessarily arrest the disease. Severe epidemics have occurred in Sweden and Russia in the depth of winter.

Even in India the seasonal curve of cholera prevalence is by no means always parallel with that of temperature In Bombay the maximum of cholera deaths is in April, in the N.W. Provinces and the Deccan in August; in Madras there are two maxima in February and September; and in Calcutta a chief maximum in April and a smaller one in November. In all these regions, except one, the highest mean temperat. is reached in May, in the N.W it is in June. In Madı cholera mortality is at its minimum in June, when the me temperature is at its highest. In Europe, as a rule, epidem attain their maximum in August, but sometimes in Septem or July.

Rainfall also has a marked influence prevalence of cholera, and supplies a clue t *the discrepancies* mentioned above. In C

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onset of the rainy season in April and May is attended with lowered cholera prevalence, although the temperature is still rising; and cholera increases again in November, when the rains terminate, although the temperature is then falling. In the N. W. Provinces the maximum cholera mortality coincides with the maximum rainfall in August, two months later than the highest mean temperature. Outbreaks during the dry season in the N. W. are usually associated with sudden rains. Both temperature and rainfall are indirect or predisposing causes only, and the maximum of either may actually coincide with small prevalence of cholera. This is readily explained if we assume, with Pettenkofer, that *moisture* of the soil (as distinguished from dryness or saturation), heat, aëration, the presence of organic matter, and the specific poison itself, are the essential telluric conditions for the propagation of cholera. Rainfall sufficient to saturate the soil (*i.e.* to raise the level of the ground water) will tend to arrest cholera, however high the temperature may be; but so long as it merely moistens a previously dry soil, the other conditions being present, rain is apt to induce an outbreak. Given a moist soil, prolonged heat and drought may be the conditions most conducive to cholera.

Soil.—A direct relation between earth temperature, at a depth of 3 to 6 feet, and the prevalence of cholera during an epidemic, has been affirmed by Pfeiffer as regards England and Prussia. Pollution, and especially animal pollution, of the soil is doubtless an important factor. The subsoil water, according to Pettenkofer, by its movement affects very materially the development of cholera as well as enteric fever. In a dry, porous soil its influence may be trifling, but in general its fall—especially after great height—leaves the soil above it moist and aërated, and is

therefore favourable to cholera if the other conditions are present. Its rise to a high level has the reverse effect. The level of the ground water in Calcutta is highest in September, lowest in May, and therefore accords closely with the inverse relation to cholera affirmed by Pettenkofer.

Epidemics are especially apt to follow the banks of rivers and lakes, whether navigable or not. Hilly regions seem to escape frequently, although outbreaks may occur on high ground. The influence of elevation is often recognisable even in the distribution of cholera in a single town.

Particular quarters, streets, and even houses are often selected for attack in a town invaded by cholera, and the selection can usually be explained by the existence of some filth condition in or about the houses, some pollution of water supply, or other insanitary condition.

Drinking-water has been closely associated with several outbreaks of cholera in England and India.

A few classical instances may be quoted here. The 1849 epidemic was very fatal in a part of London supplied mainly by two water companies—the Southwark and the Lambeth both of which distributed polluted Thames water after imperfect filtration. The incidence of cholera was substantially the same upon the customers of both companies, whose mains supplied the same districts and even houses in the same streets. In 1854, however, the population supplied by the Southwark Company suffered in 14 weeks a mortality from cholera of 13·0 per 1,000, and the customers of the Lambeth Company only 3·7 per 1,000. The disease singled out the houses supplied by the Southwark Company, whose intake remained as in 1849; while the Lambeth Company had in the meantime obtained a purer supply from a point many miles higher up the river.

The 1866 epidemic in London chiefly affected Poplar, and Netten Radcliffe found a similarly close coincidence between the area affected and the distribution of polluted water by the East London Company. In 1854 a sudden and intense *outbreak occurred* among the inhabitants of a small area near *Golden Square*, upwards of 400 persons being attacked within

five days. The incidence of the disease was limited to those who had drunk the water from a pump in Golden Square—including persons residing at a distance who had sent for the water—and upon investigation the well was found to be polluted with sewage. A few fatal cases had occurred in the vicinity during the month previous to the outbreak, and there was strong probability of specific pollution of the well.

More recently, the experience of Hamburg, Altona and other places, has afforded further proof of the possibility of convection of cholera on a large scale by drinking-water.

Air has been regarded as the usual means of convection, but there is no clear evidence of this, and many facts are opposed to it.

Race.—The incidence and severity are greater among negroes than Europeans, but apparently less among natives of hot countries in which cholera occurs than among European settlers.

Insanitary conditions of air, water, food (including milk), soil, drainage, and housing determine the points of attack. Hence the disease attacks more especially the poorest quarters of towns. Excremental filth is most dangerous of all.

The poison doubtless gains access to the system by inhalation or swallowing. The incubation period is stated to be usually a few hours to three days, but may reach ten or even twenty days (*Parkes*). The mortality is, as a rule, not far short of 50 per cent. of the cases, and may be greater. Infection is given off in the discharges from the bowels, and probably in the vomit also. These may infect water, soil, or fomites.

Bacteriology.—Koch isolated from cholera discharges a microbe which from its shape received the name of "comma" bacillus. It is a curved rod, often about half the length of the tubercle bacillus, and motile. Strictly speaking, the "comma" bacilli are segments of a spirillum or vibrio, and not true bacilli. They are present in choleraic evacuations, generally, if not always, in spirillum form. They

occur in the intestinal wall and in the detached flakes of mucous membrane, in which they often lie in parallel arrangement, creating the "fish in stream appearance" under the microscope. They do not occur in the blood, and but little in the body generally. They have been found in wells polluted by choleraic excreta. They can be readily cultivated, and have a characteristic mode of growth; they flourish in sewage, and have been found to survive for 81 days in Marseilles harbour water, but disappear in a few days from pure water (*Frankland*).

The bacillus liquefies gelatine and grows in involution forms, but does not produce spores. It is stained by ordinary aniline dyes but not by Gram's method. In cultures it grows aerobically, and produces nitrates, but can be acclimatised to anaerobic conditions, and is then more virulent but less resistant. The organism produces characteristic growth on the ordinary media and produces indol, which, with the nitrates, gives a red reaction on addition of sulphuric acid (nitroso-indol). This test is known as "the cholera-red reaction." The bacilli are killed by acid liquids, so that they cannot live in presence of the acid gastric juice, but it has been shown that the contents of the stomach may remain alkaline if only liquids are taken. Koch neutralised the gastric juice of fasting guinea-pigs by alkali, checked the peristalsis by opium, and then introduced cultivations of "comma" bacilli into the stomach. The animals died in a day or two, the intestines being filled with fluid containing numbers of "comma" bacilli. Infected water and milk, and in one case an artificial culture, have been found to convey infection. It is possible also infection may occasionally occur through the respiratory tract, but this is certainly not the ordinary mode.

The "comma" bacillus is readily destroyed by heat

or other disinfectants, or by mere drying. The organism can, however, resist cold. Spores, if ever formed, would doubtless be more resistant. Emmerich has found in cholera evacuations another still more minute bacillus, straight and immobile, which he regards as pathogenic in cholera.

That the comma bacillus is pathogenic in Asiatic cholera seems to be proved by the unintentional infection of a worker in Koch's laboratory from a culture of comma bacilli, under conditions that excluded other sources of infection. This bacillus has been "intensified" in various ways, and is then pathogenic to lower animals, including dogs and rabbits. It has also been attenuated, and a protective "vaccine" has been obtained. Haffkine prepares two vaccines, the weaker of which is made from cultures of the bacillus attenuated and the *virus exalté* from similar cultures the virulence of which has been increased by passage through animals. The first vaccine is inoculated and followed, three or four days afterwards, by the second.

Broadly, the reasons for believing Koch's comma bacillus to be the cause of cholera are (*a*) its constant presence in cases of the disease, (*b*) the results of accidental infection, (*c*) the agglutinative and protective properties of the serums of cholera patients, and (*d*) the result of Haffkine's preventive inoculation with his two vaccines.

Cholera nostras is the name given to a form of diarrhœa endemic in Egypt and elsewhere. It does not spread in epidemic form, nor does it cause high mortality. Finkler and Prior have detected in the evacuations a "comma" bacillus, which, however, differs in size and mode of growth from Koch's.

Yellow fever has its endemic areas in the West Indies and certain parts of the Mexican and West African coasts, and frequent and intense epidemics

occur between 33° N. and 23° S.—that is, from Charleston to Rio Janeiro. It is, therefore, essentially a tropical disease, but has occasionally occurred in epidemic form as far north as 43° N., at Leghorn and at Portsmouth in New Hampshire, and a few isolated cases occurred at Swansea (51° N.) in 1864 among persons who came into direct contact with infected vessels. Among European countries only Spain and Portugal come practically within its epidemic range. Infected ships reach European ports, but without causing any spread of the disease.

In the endemic area the greatest prevalence is between April and September, but in higher latitudes the epidemics occur in summer and autumn, beginning usually in July and August and never lasting beyond December. It is only endemic in regions where the mean temperature reaches 20° C. (68° F.), and epidemics do not as a rule occur in any latitude unless the temperature is above that point. A fall below 20° C., however, will not necessarily arrest the course of an epidemic when once begun, though it will usually cause a remission, but frost always arrests it more or less completely. According to Hirsch, atmospheric humidity and rainfall are as a rule favourable to yellow fever, unless accompanied by great lowering of temperature. With few exceptions the incidence of the disease is limited to the sea coast and the shores of great navigable rivers; only in intense epidemics does it affect elevated points. Even in the West Indies it rarely extends as high as 700 feet above the sea.

Yellow fever is a disease of towns, and has a strong tendency to localise itself in certain quarters, streets, or blocks of houses. Successive epidemics frequently single out the same local foci. As a rule these are in the filthiest and most crowded parts, where insanitary conditions of every kind abound, and more especially excremental pollution of the air, soil, and water. Outbreaks frequently occur on board ship, and if virulent are usually associated with similar filth conditions.

Telluric conditions have probably some influence, *but it is not* known to be conveyed by drinking-

water. Some authorities believe that wind can carry the infection for short distances.

Negroes, and perhaps also Chinese, have a remarkable immunity from yellow fever. Strangers of other races, and especially those from temperate climates, are very liable to attack. They may acquire a considerable and increasing degree of immunity by "acclimatisation," but for this it appears to be essential that they reside in a yellow-fever district for some years, including an epidemic period. It is possible that natives gain their immunity in the same way during childhood. Those who have undergone an attack are safest of all. It seems, however, that negroes as well as other persons may lose their immunity by a few years' residence in temperate climates, and even by migration from one yellow-fever district to another. Both susceptibility and severity of attack are found to increase in inverse proportion to the temperature of the native country. In Guiana the case mortality among West Indians was 7 per cent., Italians and French 17 per cent., English 19 per cent., Germans and Dutch 20 per cent., Scandinavians and Russians 28 per cent. Young and vigorous persons are said to be especially liable to attack, and men more so than women.

Yellow fever follows almost exclusively the lines of maritime traffic, and is not carried far by land. It is certain that ships may become infected and retain the infection with much tenacity, and baggage and other fomites have been known to convey infection without the intervention of infected persons. That a person whether infected or not may carry the infection with him appears to be undoubted, but the most intimate contact with the sick, wearing their unwashed clothes, occupying the same beds, making autopsies, and even inoculating the vomit, may, so it is alleged, fail to impart the disease.

The incubation is stated to vary greatly, from two or three to fourteen or sixteen days. The attack is sudden, with high fever and intense headache and lumbar and spinal pains. Vomiting sets in early, becomes incessant, and in three or four days blood is seen in the vomited matter, and often in the fæces. The urine is albuminous, and scanty or suppressed. Jaundice follows, and the patient passes into a typhoid state. A large proportion of the cases end fatally, the rest in lysis and convalescence in two or three weeks.

Bacteriology. The etiology of yellow fever is obscure, but two theories share at the present time the chief support; the first is that the disease is due to Sanarelli's *Bacillus icteroides*, the second (and more probable) that it is due to a protozoan parasite, conveyed by a species of mosquito.

Sanarelli's bacillus is an anaerobic, motile, non-liquefying, resistant organism, obtained from the blood and tissues (not the alimentary canal) of persons suffering from yellow fever. It grows on ordinary media and ferments sugar. It is decolorised by Gram's staining method. Sanarelli holds that moulds are the "natural protectors" of the bacillus.

In 1901 the United States Army Commission reported that whilst *B. icteroides* was not always present in yellow fever, the blood appeared to contain the virus, and retained it after being passed through a Berkefeld filter. The commission further reported that the disease was not communicable by direct contact, but probably by mosquitoes, as in malaria. The species of mosquito suspected was the *Stegomyia fasciata.* Preventive measures were adopted in Havana on the mosquito hypothesis, with the remarkable result that the disease was stamped out. Guitéras of Havana has carried out further experiments which confirm many of the Commission's

findings, and, in particular, the transmission of the disease by mosquitoes. A United States Army Expedition reinvestigated the subject in 1902-3, and reported that: (1) Bacteriological examination of the blood during life, and of organs and blood immediately after death, is negative. (2) *Stegomyia fasciata*, when allowed to suck the blood of a yellow fever patient 41 hours after the onset, can on biting a non-immune person 22 days later produce the disease. (3) *Stegomyia fasciata*, contaminated by sucking the blood of a yellow-fever patient, and then killed, cut into sections and appropriately stained, presents with regularity a protozoan parasite, *Myxo-coccidium stegomyiæ*, which can be traced through a cycle of developments from the gamete to the sporozoite. (4) *Stegomyia fasciata*, fed on the blood of a person with malarial fever, on normal blood, or artificially, does not harbour the myxo-coccidium.

The preventive measures to be adopted against yellow fever are the avoidance of districts in which it is known to prevail, the selection of inland, thinly-populated, and especially elevated points for residence, avoidance of the *Stegomyia* mosquitoes, and strict attention to sanitary conditions. Fatigue, exposure to sun, drinking, and improper food are said to predispose to infection.

Dengue is now known to have occurred in epidemic form in the last century, but was first recognised during outbreaks in Farther India in 1824, and in the West Indies, Mexico, and the Southern States in 1827-8. Dengue resembles influenza in the intensity of its epidemics, which often affect almost every person in a town. It spreads mainly along lines of traffic. Even in tropical countries its prevalence is greatest in the hot season, and elsewhere it occurs only in summer and autumn, and in years of high temperatures. It affects maritime towns, and rarely spreads inland. Low-lying, filthy and overcrowded quarters are the first to be attacked. After a short incubation of two to four days the onset is sudden, with rigors, pyrexia, and acute pains and tenderness in the small

joints of the hand and feet. Very soon the large joints become affected, then the bones and muscles, and the head and back. A transient erythema appears at this stage in half the cases. In one or two days a remission or intermission of all the symptoms occurs after profuse sweats having a pungent odour, but after a short interval the symptoms return in a modified degree, often accompanied by glandular swellings, and a rash which as a rule consists of irregular red elevated spots. The second febrile stage passes off in three or four days at longest, and slow convalescence follows. Dengue is fatal only in debilitated persons, or in the very young or old. In some epidemics the disease has apparently attacked cattle, dogs, and cats.

Plague, first introduced from the East, and possibly identical with the Black Death of the Middle Ages (1348), was frequently epidemic in England up to the time of the Great Plague in 1665. In the following century it retreated eastward, and disappeared from Europe in 1841 and from Egypt in 1844. In Asia it has lingered on endemically in certain temperate regions, and of late has shown renewed activity, especially in India. Grave epidemics have occurred at Canton, Bombay, and elsewhere, and infection has been brought in recent years by ship to Great Britain, but without spreading. Plague is an infectious filth disease, fostered by destitution, uncleanliness, overcrowding, and lack of ventilation.

There are four chief varieties of plague: the *bubonic* form, the most common and typical, the lymph glands being chiefly affected in the groin, the axilla, or the neck; the *septicæmic*, in which the bacillus reaches the blood; the *pneumonic*, in which the lungs are mainly affected; and *pestis minor*, in which the affection of the glands stops short of the septicæmic stage, and even the local symptoms are slight. There are certain symptoms common to all forms of plague, when at all severe. An ordinary attack of plague usually begins three to five days *after infection*. Such attack may develop gradually,

but, generally, there is sudden onset with much fever, as indicated by a high temperature, rapid pulse, headache, backache, hot skin, and thirst. The eyes are injected as if inflamed; the expression, at first haggard, anxious and frightened, becomes subsequently vacant, listless, and dull; the utterance is thick, and the gait unsteady as in one under the influence of alcohol. Mental aberration develops quickly. There is frequently a marked tendency to faint. The tongue is at first covered with a moist white fur except at the edges, which are red, but later on it becomes dry and of a mahogany colour. Vomiting and nausea are present from the onset. Sleeplessness is a characteristic symptom. The most distinctive sign, however, is the presence of swellings, or "buboes" in the groin, armpit, or neck, which appear on the second or third day of the disease, as large, smooth, tense swellings, painful and tender on pressure, and in size varying from that of an almond to that of an orange.

Cases occur in which these manifestations of the diseases are greatly delayed or even absent, as, for instance, in "pneumonic," "gastric," and "septicæmic" plague; forms of the malady which may be mistaken respectively for inflammation of the lungs, typhoid fever, or acute blood poisoning. Plague in these forms is always grave; not only because of the fatality of the cases but for the reason that they are highly infectious to other persons. It is important, therefore, that in localities where plague is present or is threatened, cases of anomalous illness of the above sorts should be, without loss of time, brought under medical supervision.

There is also the so-called "ambulant form." In plague of this description the affected person is hardly ill at all, presenting no definite symptoms perhaps beyond indolent, though painful, swellings in groin or

armpit. Such plague cases may nevertheless be instrumental in spreading the disease.

Bacteriology.—The causal organism, *Bacillus pestis*, was discovered in 1894 by Kitasato in the blood of patients suffering from the disease. It is a small, round ended, oval cell, with marked polar staining, hence presenting an appearance not unlike a diplococcus. In the middle there is a clear interspace, and the whole is surrounded with a thick capsule, stained only with difficulty. The organisms are non-motile and often linked together in pairs or even chains (especially in fluid cultures), and exhibit polymorphic forms. In culture the bacillus may be coccal or bacillary in form.

It grows readily on the ordinary media at blood-heat, producing smooth, shining circular cream-coloured colonies, with a wavy outline, which eventually coalesce to form a greyish film If melted butter (or *ghee*) or oil be added to bouillon, the bacillus grows in "stalactite" form. The following negative characters assist in differentiating the bacillus: There is no growth on potato; milk is not coagulated; gelatine is not liquefied; Gram's method does not stain the bacillus; and there are no spores. The bacillus is readily killed by heat or by desiccation over sulphuric acid.

In the body the bacillus chiefly frequents the spleen and lymph glands, the latter becoming inflamed, especially the inguinal and axillary.

Haffkine has prepared a vaccine which diminishes the incidence and fatality of the disease in inoculated populations, although the degree of protection is not perfect. The vaccine is made from a six-weeks' old broth culture of *B. pestis*, sterilised at 65-70° C. for an hour, and preserved in bottles containing 0 5 per cent. carbolic acid. The dose is 5-10 c.c.

The disease is personally infectious, and is thus

spread. Rats also convey the infection from port to port, and one of the necessary means of prevention is the extermination of rats. These animals generally suffer from plague before the disease breaks out among men.* Preventive measures, therefore, include vigorous disinfection of infected houses and the extermination of rats. The latter may be accomplished by various rat poisons, and on board ship also by carbonic acid gas.

Malarial diseases may conveniently be considered as a single group, although they include many varieties that have received specific names. All have a characteristic tendency to periodicity in the course which the symptoms follow, and this peculiarity is made the basis of a broad subdivision into intermittent and remittent types of fever, the former being the less severe. Intermittent fever or *ague* is further subdivided into quotidian, tertian, and quartan varieties, according to the length of interval between the attacks, which may occur every two, three or four days. Each attack is marked by a cold stage, a hot stage, and a sweating stage; but the temperature in the intervals always becomes normal. Of these sub-varieties, quotidian ague, with daily attacks, is the most severe, has the longest hot stage and the shortest cold stage, and approaches the most closely to the remittent type. In

* A recent case illustrating the conveyance of infection by rats may be quoted. On July 26th, 1904, the s.s. *Bishopsgate* left Rosario for Hamburg. She arrived on August 29th, with the crew all well. On September 6th, on discharging the cargo (wheat, maize and bran), dead rats were found, and on bacteriological examination some were found to be plague infected. During the voyage, and until the unloading, the holds had been closed, and the infected rats confined to this part. The vessel was thoroughly fumigated with a mixture of carbon dioxide and carbon monoxide to destroy all the remaining rats, and afterwards the holds were limewashed and the crew's quarters disinfected. A new crew was shipped on September 15th, two days before the vessel left Hamburg for the Tyne, but the boatswain had been engaged for a week previously to assist in clearing up decks and holds before and during the disinfection. On September 18th he complained of illness, which proved to be plague. *B. pestis* was found in the blood and lymph from the buboes.

remittent fevers there are one or two exacerbations every day, but the temperature during the intervals does not subside to the normal level, nor do the constitutional symptoms entirely disappear. The cold stage is very short and the hot stage protracted. Remittent fevers are met with principally in tropical regions, but are endemic in many marshy districts in Southern Europe, and occasionally spread as far north as the Baltic.

General conditions.—As the intensity of the endemic or epidemic prevalence diminishes, the individual cases tend to assume more and more the intermittent type. Broadly speaking, the tendency to malaria increases with the temperature, especially if the diurnal range of temperature is high. Atmospheric humidity is also favourable to malaria. Moisture of the upper part of the soil is an almost invariable condition of malarious districts, and the effect has been said to be heightened by a slight superficial drying. Clay soils, which retain moisture, are among the worst, but chalk, or sand, or other porous soil, may become highly malarious if from any cause the subsoil water is high. Malarious soils almost always contain vegetable matter in greater or less quantity. In such districts heavy rainfall, especially after long heat and drought, is generally followed by outbreaks of malaria, and irrigation has a similar tendency. They cease to be malarious when the ground is either completely flooded or dried—temporarily or permanently—by drainage and extensive planting (*e.g.*, with *Eucalyptus globulus*). As regards the surface, the prevalence of malaria decreases with the elevation, other things being equal. High ground is the most healthy, but exception must be made in respect of spurs of hills and depressions even at high levels, and more particularly of ravines. Among other causes conducive to malaria are abandonment of cultivation, or, on the other hand, the breaking up of new ground, excavation, or cutting down trees. Volcanic disturbances and earthquakes have, it would appear, sometimes been followed by malarial outbreaks. Fodor concludes from observations at Pesth that only the superficial layers of the soil are concerned in producing conditions favourable to malaria.

Such being the general characteristics of malarious districts as regards climate and soil, it must next be pointed out that *they are in themselves* inadequate to produce malaria, and also

that some of them are entirely wanting in highly malarious localities. Malaria is unknown, for example, in many parts of Ireland, in the Bermudas, and the Pampas of South America, where the physical conditions would *à priori* appear to be highly favourable. On the other hand, some of the malarious districts in the Deccan and Mysore are steep mountain slopes, and many others in India and elsewhere are equally free from moisture of the soil. Instances are common in which districts, previously healthy, become temporarily or permanently malarious, without apparent change in their physical conditions. Malaria being a specific disease, the presence of a specific organism is necessary, and the conditions above described are to be regarded merely as more or less favourable to its growth and dissemination.

The Etiology of Malaria.—In 1880 Laveran first discovered and described parasites in the blood cells of malarial patients, and on further investigation it was soon found that these assumed many different forms. These differences depend upon the *kind* of fever and the *stage* of fever. The reasons for believing that Laveran's bodies—though they have not yet been cultivated outside the human body—are the specific cause of malaria are that the parasites found in the blood of malarial patients of all countries are the same, and such parasites are not found in healthy persons; that their development fully accounts for the production of the melanæmia and malarial pigmentations of viscera owing to the melanin-forming property of the parasite; that the phases in the development of such parasites correspond with the clinical course of malaria (*Golgi*); that quinine, which cures malaria, kills the parasite; and that malaria can be conveyed by the introduction of this parasite into the blood of man, and the parasite reappears in the blood of the individual so inoculated. Laveran's bodies have been variously classified as knowledge of them has grown. It is now agreed that these parasites belong to the *Sporozoa*, to the order of *Hæmocytozoa* and to the genus of *Hæmamœba*. They gain access

to the blood corpuscles in which they develop, producing *sporocytes* which, on the rupture of the corpuscle, become free in the blood and attack other corpuscles passing through the same changes (the cycle of Golgi), and resulting in a fresh generation of spores. The exact changes, however, depend partly upon the form of disease (quartan, or benign tertian, or malignant quotidian), but much more so upon the immediate needs of the parasite, that is to say, whether the development is to be in the human body only and asexual, or in the mosquito and sexual. (*Manson*, *Ross*, and others.) If it is to be the latter the amœbula does not sporulate in the corpuscle, but becomes a crescent-shaped body absorbing the corpuscle. These crescents, or *gametocytes*, are of two forms, male and female, and are the first stage in the extra-corporeal stage of the life-cycle, that is to say in the mosquito. The male gamete (*microgametocyte*) develops flagella, which are of the nature of spermatozoa, and break off from the cell and become free in the blood of the mosquito. The female crescent, or gamete (*macrogametocyte*) starts in the same way as the male form, but becomes spherical and extrudes two polar bodies, receiving at the site of extrusion an impregnation by the free flagellum of the male cell. The result is a *zygote*, a travelling vermicule, which passes into the stomach wall of the mosquito, and becomes encysted there, and eventually reproduces spores or *sporozoits*. About the twelfth day it bursts, discharging the reproductive elements into the body cavity of the mosquito, which, passing from thence, become accumulated in the salivary gland, and are thus in position to be injected into the blood of the next human being bitten by the mosquito. In the human blood again they attack the corpuscles, and recommence the asexual life cycle. Just as the *sporocytes* are the means of propagating the parasite in the blood, so the flagellated body and

sexual cycle is the means of propagation in the mosquito.

The species of mosquito which has been shown to be the host of the malaria parasite is the *Anopheles*, the body of which is slim, the proboscis long and thick, the palpi long, and the wing "dappled" with dark spots on its anterior margin. It is a "puddle-breeding" insect. The common mosquito, or *Culex*, has short palpi, thick body, thin proboscis and unspotted wings. It is a "pot-breeding" mosquito. Certain conditions are necessary for the multiplication of malarial mosquitoes, namely, high atmospheric temperature, 75-104° F., collections of water, fresh or brackish, and the presence in the breeding pools of low forms of animal and vegetable life. Many of the physical conditions hitherto cited as favourable to the disease are now seen to be favourable to the specific mosquito, and their relationship to malaria is thus, in part, explained. The prevention of malaria depends upon the fulfilment of four chief requirements:—(1) The prevention of mosquito breeding by land-drainage and removal of collections of water; (2) the destruction of mosquitoes (*Anopheles*) and of their eggs, larvæ, and nymphæ; (3) avoidance of mosquito bites, and (4) the therapeutic and prophylactic use of quinine.

Leprosy is a disease of great antiquity in Egypt, India, China, and Japan. The Biblical term "leprosy" doubtless included many forms of skin disease, and the same ambiguity attends most, if not all, of the other records of the disease in former ages.

Leprosy has been especially confounded with syphilis and *elephantiasis arabum*, true leprosy being sometimes termed *elephantiasis græcorum*. It probably made its appearance in Europe about the beginning of the Christian era, and became widely diffused during the next eight or nine centuries. A further increase—attributed by some to the Crusades—took

place in the twelfth and thirteenth centuries, but in the fourteenth and fifteenth centuries it began to disappear, and at the present time has vanished from Europe, with the exception of certain limited districts, more especially in Norway, Sweden, Finland, Spain, Portugal, and some parts of Italy, Greece, Turkey, South Russia, and some of the Mediterranean islands, including Sicily and Cyprus. It is prevalent in the West Indies, the west coast of South America, India, China, and the greater part of Asia; most of the islands in the Pacific, notably Hawaii, and in many parts of Africa. It is common in Mexico, and minor foci exist in Louisiana, New Brunswick, and British Columbia. Special attention has recently been directed to its increase at the Cape. Districts upon or near the coast are by far the most frequent seats of endemic leprosy.

In England, special legislation was directed against leprosy in the tenth century, and leper hospitals were established in the eleventh, twelfth and thirteenth centuries in many of the larger towns. The last record of any extensive prevalence in England was at the end of the seventeenth century, and it is now unknown except as a disease acquired abroad.

Leprosy is diminishing in its few remaining European centres, but probably slowly increasing in the West Indies, Demerara, South Africa, and some other countries. Chinese immigration is said to have introduced it into North Australia and British Columbia.

General conditions.—Climate would appear to have little influence, since the geographical distribution is or has been almost world-wide, nor has anything been made out definitely in regard to more local meteorological conditions. The effect of season, if any, cannot be traced in a disease which begins insidiously and runs a protracted course. The greater incidence upon coast regions seems to give a clue to the etiology, but the disease prevails in elevated regions far removed from the sea. The use of fish, and especially of decomposing fish, as a principal diet is supposed to contribute largely to the causation of leprosy (Hutchinson). This view is supported mainly by the *prevalence of the* disease in littoral districts, but

also to some extent by its frequent appearance in new regions among Chinese settlers, whose skill in cookery enables them to make use of putrid fish, and lastly by its observed disappearance from certain districts where fish diet ceased to be general. On the other hand, there are many inland leprous regions in which fish is rare, or, as in Central China, limited to the use of the wealthier classes. The disease has declined in many localities without any material change in diet, and, further, the vegetarian Brahmins are by no means exempt from leprosy. It would seem, therefore, that a fish dietary, if it has any etiological significance at all, is not operative in all cases. Another hypothesis is that deficiency of common salt in food is conducive to leprosy. Sanitary improvements in the habits and surroundings of the population have, in all probability, been chiefly instrumental in suppressing leprosy in England and elsewhere. Although never confined to the poorer classes, its incidence has been greater upon those living in filthy and unhygienic conditions.

Nothing is known as to any relation with telluric conditions, or transmission by water or air. Negroes, Hottentots, and Chinese are more affected than white races living in the same localities. Males suffer in greater numbers than females, and among the very old and the very young the disease is of rare occurrence.

Authorities are at variance as to the hereditary transmission of leprosy, and very little is known of the way in which the disease is ordinarily acquired. It is communicable by direct or indirect means, from the sick to the healthy, and there is no certain evidence of its arising or spreading in any other way. Hansen states that no sign of leprosy had appeared among the descendants of 160 Norwegian lepers who settled in the United States. Arning has proved it to be inoculable, having successfully inoculated a condemned convict.

Clinical characters.—The incubation period in Arning's case was two years. It is believed to be very variable, extending over months or years, with or without premonitory symptoms. Three chief types are described (*a*) the anæsthetic (or maculo-anæsthetic), (*b*) the tuberculated, and (*c*) the mixed. The anæsthetic form causes a destruction of nerve fibres, the tuberculated chiefly affects the skin, resulting in a nodular growth or diffuse infiltration. It produces marked disfigurement. The average duration is given as eight years in the former and sixteen in the latter, but with wide variations. When the disease begins in early life, its duration is comparatively short. The result is almost always fatal, but it is stated that in Norway thirty-eight cases were cured in the five years 1881-5, and Kaurin believes that if the disease is localised, early amputation may sometimes permanently arrest it. According to Sand, the disease may exhaust itself in thirty or forty years if the constitution is exceptionally strong.

Bacteriology.—The *B. lepræ* was discovered by Hansen in 1874. It is present in enormous numbers in the skin and tissues, and has a form very similar to *B. tuberculosis.* Spores have not been seen, but Neisser holds that this is the form in which the bacillus gains entrance to the body. The arrangement in clumps and colonies inside the round cells is useful for diagnostic purposes. The bacilli are also found free in the lymphatics, inside connective tissue cells, in the walls of blood vessels, in the lymphatic glands, and in the internal organs. Bordoni-Uffreduzzi, Carrasquilla (1899), and Campana claim to have isolated the bacillus and grown it on artificial media, the two former aërobically on peptone-glycerine-blood-serum, at 37° C., the last named anaerobically. Cultivated bacteria from the organs of lepers, described rather later by Babés, and still

more recently by Czaplewski, differ from the genuine bacillus of leprosy in their incomplete resistance to acids. There is little doubt that the disease is produced by Hansen's bacillus. Bordoni-Uffreduzzi holds that the bacillus has a saprophytic stage in its life cycle.

Hansen, Ehlers, and others believe that the disease is spread by contagion, Virchow held the reverse opinion. Besnier and Sticker consider the infection is conveyed in nasal secretion. The Leprosy Commission in India (1890-91) reported that—

(1.) Leprosy is a disease *sui generis*; it is not a form of syphilis or tuberculosis, but has striking etiological analogies with the latter. (2.) It is not inherited, and has a natural tendency to die out. (3.) Though contagious and inoculable, the extent to which it is propagated by these means is exceedingly small. (4.) It is not directly originated by the use of any particular article of food, nor by any climatic or telluric conditions, nor by insanitary surroundings, neither does it peculiarly affect any race or caste. (5.) It is indirectly influenced by insanitary surroundings, such as poverty, bad food, or deficient drainage or ventilation, for these increase the susceptibility.

Preventive measures.—The practical suggestions of the Commission for preventive treatment included voluntary isolation of the sick; prohibition of the sale of articles of food by lepers; leper farms; orphanages; and "improved sanitation and good dietetic conditions" generally. Serum-therapy has been attempted, but without success. Up to the present time no curative agent has been found.

In Norway, leper asylums were established in 1856, and the number of lepers is believed to have steadily declined. The isolation in these asylums is not rigid, but in Hawaii an island is set apart for the leper settlement, and the seclusion is practically life-long. It seems clear that the infection is not acquired readily, if we take the ordinary infectious diseases as

a standard, and there is some probability that even a partial segregation of lepers may have considerable influence in arresting the disease, assuming its spread to be due mainly to personal intercourse. The difficulties of obtaining a tolerably complete isolation or even registration of lepers are of course very great.

Malta fever (Mediterranean fever) is common along the coast of the Mediterranean and in its islands. It is a disease of long duration and variable symptoms, including remittent fever. Perspiration, pains, swelling of joints, enlargement of the spleen, etc., are among the common signs. In 1887 Bruce cultivated from the spleen the *Micrococcus melitensis*, a small round or slightly oval coccus, occurring singly, in pairs, or in chains. It can be cultivated from the spleen, on agar at 37° C.; colonies appear about the third day as small, round, slightly raised growths; old cultures assume a buff tint. Cultures retain vitality for long periods. The organism is present in the peripheral blood in all cases during the early stages of the disease, and in severe pyrexial relapses. It has been isolated from the urine. The disease is inoculable in animals.

Sleeping sickness is probably caused by the entrance into the blood, and thence into the cerebrospinal fluid, of a species of trypanosome (probably the *Trypanosoma gambiense*), which is transmitted from the sick to the healthy by a tsetse fly (*Glossina palpalis*), and, apparently, by it alone. It has been demonstrated by experiment that not only were these flies, fed on sleeping sickness cases, capable of conveying the disease to healthy monkeys, but that freshly caught flies from an infected area, without any artificial feeding, were also capable of conveying the disease. This fly, like its congener the tsetse fly of South Africa, is confined to well defined areas, which correspond *absolutely* with the distribution of sleeping

sickness; whereas, in regions where no *Glossina palpalis* is found, although other biting flies abound, there is no sleeping sickness. While a large percentage of the inhabitants of the sleeping sickness areas have the trypanosome in their blood, in not a single inhabitant of non-sleeping sickness areas was this parasite found. Monkeys inoculated with cerebro-spinal fluid from sleeping sickness patients, or with blood from natives not as yet showing symptoms of sleeping sickness, but containing a similar parasite, sickened and died with all the symptoms of sleeping sickness. As in the case of ankylostoma, individuals may have this trypanosome in their blood, and yet reveal no symptoms of the disease. A Portuguese Commission laid emphasis upon a diplo-streptococcus which a number of observers have found to be present.

The disease has spread in the Congo region, Uganda, and northwards along lines of communication, that is rivers, and has become a scourge in certain riverine tribes. Clinically the early stage of sleeping sickness may be recognised by enlargement of the cervical glands (polyadenitis), enlargement of the spleen, œdema, and certain pathological conditions of the blood, including lymphocytosis. Sleeping sickness is probably the last stage of a disease and seems to be invariably fatal.

Dysentery.—Endemic or tropical dysentery is possibly due to *Amœba coli vel dysenteriæ.* Epidemic dysentery is more probably due to *Bacillus dysenteriæ*, and sporadic and parasitic dysentery to various parasites, such as *Balantidium Coli* and the *Bilharzia.* Mott holds that "asylum dysentery" is identical with tropical dysentery, and that both conditions are in all probability of bacillary origin.

The disease is not confined to tropical climates. At one time it was "one of the most prevalent and fatal diseases of London" (*Baly*). It is believed to

be influenced by season and soil, autumn and polluted subsoil favouring its occurrence, though personal predisposing conditions doubtless play an important part. From a sanitary point of view water supply, dietary, and uncleanliness are the conditions into which inquiry should be made. It is probable that the excreta serve as one of the chief media of infection, and they should therefore be disinfected. Apart from institutional outbreaks (*e.g.* asylum dysentery) dysentery is a comparatively rare disease in this country.

Beri-beri is endemic in Western India, in the India Archipelago, China and Japan. It is mostly confined to the working classes, and is said by some to be due to an organism infecting rice; others consider it a "place disease," and Durham holds that it is more a "gang" or "institutional" disease. It is a kind of scurvy of the tropics, affecting the underfed, and is characterised by weakness, dropsical distension of the abdomen, limbs, and face, and many of the features of alcoholic neuritis. Probably the disease is communicated from person to person directly or through fomites.

CHAPTER XVI.

PREVENTION OF INFECTIOUS DISEASES.

In the preceding chapters reference has been made to the various means by which specific and other diseases are disseminated or checked. It remains to consider the powers and duties of the **S.A.**, and of the **M.O.H.**, in relation to preventible diseases, and especially infectious diseases. All infectious diseases may be said to be preventible, but not all are amenable to the preventive measures which at present can be enforced by the most active sanitary administration. Small-pox and rabies may be taken as types of specific diseases which can be and ought to be suppressed, and are now, as a matter of fact, limited to such persons and such populations as do not choose to adopt the measures which reiterated experience has shown to afford safety. Measles and whooping cough, on the other hand, although strictly speaking preventible diseases, always dependent (so far as we know) upon direct or indirect infection from other cases, have not yet been brought under control. No prophylaxis has been discovered, and as infants are especially liable, the susceptibility of the population is speedily renewed, even after an outbreak. Isolation and disinfection are theoretically capable of arresting the spread of these diseases if applied in every case and at the commencement of the infectious stage, but in practice this can scarcely be accomplished at present, for reasons that will be stated later.

Scarlet-fever, diphtheria, and enteric fever are examples of a different class. They are not entirely dependent upon infection from person to person, but are affected by a variety of conditions of which every

year brings us fuller knowledge. Some of these conditions, including personal infection, infection from lower animals (by consumption of milk or flesh, or in other ways), and infection by drinking-water, are more or less under our control. So, too, are the various "insanitary conditions" which conduce to the spread and malignancy of specific diseases, and telluric conditions also are to a great extent remediable. Experience has shown that if carried out thoroughly, isolation, disinfection, and quarantine can very greatly reduce the incidence of these diseases, but there is always danger from unrecognised cases, from the early stages of the disease before the diagnosis is made, from importation of infection, and from accidental or wilful neglect of precautions. It must also be remembered that there may be modes of infection in these diseases at present unknown to us, and this is especially probable in respect of diphtheria.

Compulsory notification of certain infectious diseases rests in London upon the Public Health (London) Act, 1891, and elsewhere upon the Infectious Diseases (Notification) Act of 1889, as amended by the Infectious Diseases (Notification) Extension Act of 1899, which also enables any **S.A.** with the sanction of the **L.G.B.** to add temporarily or otherwise other infectious diseases to those scheduled in the Act, which are—small-pox, cholera, diphtheria, membranous croup, erysipelas, scarlet-fever, typhus, enteric fever, relapsing fever, continued fever, puerperal fever. The inclusion of membranous croup in the list tends to make the reporting of diphtheria more complete, and "continued fever" covers obscure cases of enteric fever, or possibly typhus. A large number of trivial cases are reported as erysipelas, but the disease has practical importance in connection with vaccination and puerperal fever.

Doubt having arisen as to the meaning to be attached to "puerperal fever," the Royal College of Physicians have expressed the opinion that it should be understood to include "septicæmia, pyæmia, septic peritonitis, septic metritis, and other septic inflammations in the pelvis occurring as the direct result of childbirth."

Certain minor diseases such as chicken-pox may be made notifiable temporarily or otherwise in order to ensure detection of more serious complaints such as smallpox.

Forms of certificate are supplied to every practitioner practising in the district, and a fee of 2s. 6d. is paid to him for each certificate regarding a private patient and 1s. for each case in public practice. "Every medical practitioner attending on, or called in to visit, the patient shall *forthwith*, on becoming aware that the patient is suffering from an infectious disease to which this Act applies, send to the **M.O.H.** for the district a certificate stating the name of the patient, the situation of the building, and the infectious disease from which, in the opinion of such medical practitioner, the patient is suffering." The penalty for default is a fine not exceeding 40s. Under the same penalty the householder is compelled to notify, but in a less formal way, and without receiving any fee. The Act applies to "every ship, vessel, boat, tent, van, shed, or similar structure used for human habitation," but not to any "hospital in which persons suffering from an infectious disease are received." It gives no power of compulsory removal of patients to hospital, nor even power of entering upon the premises for the purpose of making inquiries, but it is very rarely that any difficulty is met with in the latter respect.

Among the advantages to be derived by the **M.O.H.** from compulsory notification are the following:—

1. Early and complete knowledge of all the cases of noti-

fiable disease, and thus of the whole prevalence and distribution in the district Death-returns give only a small fraction of the cases, and after an interval of many days or weeks.

2. Power to exercise such supervision as may be necessary over every case during its whole course, and to enforce due observance of the provisions of the Public Health Act as regards isolation and disinfection This has special importance in connection with outbreaks of scarlet-fever, diphtheria, or enteric fever in dairies, schools, etc.

3 Opportunity of offering, and in some cases compelling, removal to hospital in every suitable case, unless the **S.A.** has failed to provide hospital accommodation. Vaccination can be offered, and is rarely refused in households invaded by small pox

4. Opportunity of investigating the sanitary conditions of all households in which cases of enteric fever, or diphtheria, or other notified disease may occur.

5. Power to control the spread of infection through schools or other centres, by excluding members of infected households.

6. Means of detecting at once any suspicious grouping of cases around schools, milk supplies, water supplies, or other common foci. A comparison of the data obtained by the routine inquiries into each notified case will at once reveal this, although there may be nothing in any single case to arouse the suspicions of the friends or of the medical attendant

In several towns it has been found possible, with the aid of notification, to isolate in hospital all the cases of small pox and three-quarters, or more, of the scarlet-fever, and to establish a *cordon* of vaccination around each new small-pox centre. Very few towns have made adequate provision for the hospital isolation of enteric fever, nor is there as yet any absolutely reliable prophylactic such as vaccination to be offered, and, moreover, the danger of spread of infection from person to person by ordinary proximity or contact is less marked than in small-pox or scarlet-fever, hence notification brings to bear comparatively slight reinforcements of preventive measures, but it has great value in bringing to light any grouping of cases around a water or milk supply or other common *cause*. *Diphtheria* is more readily communicated

from person to person, but in other respects the same considerations apply. The notification of diphtheria can scarcely be complete or satisfactory, owing to the number of slight and almost undistinguishable cases, and hospital isolation upon an adequate scale has not yet been tried.

Epidemic prevalence of disease is determined by many causes, of which some are still unknown to us, and others (including climatic conditions) are beyond human control. Against such influences, unless they should prove to be operative merely by increasing the facilities for the spread of infection in ordinary ways from person to person, notification and the precautions which it renders possible are of no avail, and epidemics will continue to occur in spite of it. Nevertheless the known and preventible causes, such as the transmission of infection from person to person, or by means of milk, are factors of the utmost importance, and it is safe to affirm that, however great or however small may be the total number of victims, the suppression of known and preventible favouring conditions renders the danger less than it would otherwise have been. Individuals may be saved, and widespread outbreaks delayed, restricted, or averted.

The question whether measles ought to be added to the list of notified diseases is an important one. It is more than doubtful if any legislation could at present bring about a complete notification of measles, and, if such could be obtained, whether it would be worth while, for the following reasons. (i.) Medical advice is frequently not taken in mild forms of measles. (ii.) It is a purely epidemic disease, which has no relation to water or milk supplies, or to defects of drainage. (iii.) There is no *vaccination*. Isolation and disinfection are, therefore, the *sole preventive* measures which could be brought to bear against measles, even if it were possible to

obtain complete notification. Isolation in the homes of the poor is impracticable, and isolation in hospitals would entail a formidable addition to their present size. The results of isolation also are far less likely to be satisfactory in measles than in scarlet-fever, and as a very large proportion of the sufferers are infants, there would be great reluctance on the part of parents to consent to removal. (iv.) Infection begins generally at least three days before the rash appears. (v.) There is a long incubation period which adds to the difficulty. (vi.) Lastly, measles is often so widespread that few susceptible children among the working classes escape, and measures of notification and isolation would be on too vast a scale to make them worth while.

That valuable information would be derived from notification of measles cannot be doubted, and from this point of view its inclusion in the schedule of notified diseases is desirable. It is urged, also, that even an incomplete notification would be invaluable in rendering possible early control over school-infection; that hospital isolation of measles would no longer appear impracticable if epidemics were not allowed to proceed unchecked; and that notification of measles would bring to light many cases of scarlet-fever which, in the absence of any medical inspection, are regarded by the parents as "only measles." This last argument points to the notification of rotheln and chicken pox.

The same considerations apply to whooping cough also. About 2 per cent. of the sanitary authorities of Great Britain have voluntarily made measles a notifiable disease for a longer or shorter period. On the whole, however, the system has not been of permanent value. In London in 1904 the disease was scheduled under the Public Health (London) Act as a "*dangerous* infectious disease" to which sections *dealing with* disinfection, exposure of persons, etc.,

should apply. Voluntary notification has also been applied to phthisis in a number of sanitary districts, including Manchester, Brighton, and many of the metropolitan boroughs. In Sheffield, by a local Act of 1903, compulsory notification of phthisis has been established for an experimental period of seven years.

The regulations of the L.G.B. require that upon receiving information of any outbreak of dangerous infectious disease the M.O.H. shall at once make full inquiries, and adopt such precautionary measures as he may consider requisite. The necessary inquiries and investigations are simplified and made more systematic by the use of printed forms with spaces for the insertion of the details for each notifiable disease. Those used for scarlet-fever, enteric fever, and diphtheria, should give prominence to the details of milk supply and other channels of infection.

The following inquiries should be made in all cases:—

1. *Patient.*—Address, name, sex, age, date of onset, date of rash, present and past isolation, probable source of infection, recent contact with infected persons or things.

2. *Household* (including patient).—Sex and age of each inmate, susceptibility (as shown by history as to previous attack), date of previous attack (if any), occupation, place of work or school, and date of last attendance thereat.

3. *Work or business carried on in the house.*

4. *Water supply* and *milk supply.*

5. *Sanitary condition* of premises and surroundings.

6. *Previous cases* of the disease, or of conditions allied to it or simulating it in the home or in the vicinity, or at the school or work-place.

7. Possible sources of infection:—(1) Visits; (2) Visitors; (3) Place of work; (4) Food, milk, ice cream, shell fish, watercress, etc.—what, when, where purchased, condition; (5) Water; (6) Previous cases of sick headache, sore throat, or diarrhœa in the house or neighbourhood; (7) School, including Sundays; (8) Drain nuisances, at or near house; (9) Tailoring, washing, mangling.

In dealing with an outbreak of small-pox, further inquiry must be made regarding the condition of each individual as to vaccination and revaccination, noting the dates.

In enteric and diphtheria cases note should be taken of the previous state of health of the patient, the duration of his residence in the house, and the occurrence of any sickness among domestic animals.

The precautionary measures to be enjoined, and if necessary enforced, will vary with the nature of the disease and the circumstances of each individual case.

Registers of sickness.—From the report sheets more important details can be entered in registers, a process which involves very little cost of trouble and time, and gives a comprehensive view of the facts that cannot be attained in any other way. Each disease should have its separate register, the columns of which may be headed as follows:—

No.
District
Address.
Name of patient.
Occupation.
Sex
Age.
Date of onset.
" " notification.
" " receipt of ditto.
" " removal to hospital.
" " disinfection
Result, and date of recovery or death.
Place of work or school
Date of last attendance at ditto
Milk supply.
Water supply.
Sanitary notes
Reference to other cases
Other cases in household.
Medical attendant.
General notes, as to precautions, history, etc
(Vaccination: date and condition.)

If such registers are kept systematically, any suspicious grouping of cases in any given locality, or in connection with any particular water supply, milk supply, school, or workplace, cannot fail to attract attention at once.

Disease maps.—Maps showing the distribut of disease according to locality can be readily prep from the information given in the report sheet.

registers. A large-scale map is needed for crowded districts. Each disease being represented by a particular colour, a spot of this colour or a coloured pin is placed on every house invaded by the disease in question. Each map may serve for one or more diseases, and for a whole year, or such shorter time as may be determined.

Isolation of the patient.—Hospital isolation should be urged in all cases where practicable, and can be enforced under the conditions specified in the Public Health Act, 1875, s. 124, and the Public Health (London) Act, 1891, ss. 66 and 67. Much may be done by persuasion, by pointing out the benefit to be derived by the patient as regards nursing, food, and greater liberty during convalescence, and by explaining the protracted course of the disease, the risk of infection, and the inconvenience or impossibility of maintaining due isolation at home. There will rarely be much difficulty in removing small-pox cases (*see* pp. 218-228).

Failing removal to hospital, the arrangements for **home isolation** must be made as complete as possible, but in an ordinary household of the working class due isolation is impracticable, except perhaps at first. In large households it may be possible to obtain complete isolation and to maintain it throughout the illness upon the lines indicated below.

(i.) *Arrangement of the sick room.*—The patient should be kept in one or two rooms, preferably at the top of the house, or in a detached wing, exclusively set apart for his use. A fire should be kept burning for the sake of ventilation and destroying waste material, even when not required for heating purposes. It tends to secure an indraught at the door, but provision must be made for the constant entry of fresh air by the window or other ventilator. The door must be kept shut. A sheet is often hun

outside the door, and is useful in some ways; but little is gained by wetting it with "disinfectant" solutions, since any infected air which might escape would pass under or round it rather than through it. No one except the persons in actual charge of the patient should be allowed to enter the room. No one should leave the room without washing hands and changing outer garments, and an adjoining room may be used for this purpose. No food should be taken out of the sick room, nor any clothing or utensils without previous disinfection. Any effluvia in the room should be prevented or removed by free ventilation; and, if necessary, the air may be "sweetened" by the moderate use of sanitas, thymol, chloride of lime, or other deodorant, in the form of spray; but deodorants should not be regarded as disinfectants, and in other parts of the house they serve no useful purpose whatever.

(ii.) *Disinfection during the illness.*—A plentiful supply of 1 per 1,000 mercuric chloride solution (or 10 per cent. carbolic solution) should be provided. Disinfection of excreta and secretions may be attempted by adding an equal bulk of the solution, which may with advantage be placed in the vessel before receiving the excreta. Old linen should be used in place of pocket-handkerchiefs, and after use thrown into the fire. Linen, etc., requiring washing should be placed in a large vessel filled with the disinfectant solution; such articles should subsequently be rinsed in water before washing, to remove the disinfectant. All utensils should be similarly disinfected before leaving the room.

(iii.) *Final disinfection at the end of the case.* (*a*) All linen, cotton, and silk articles which can be removed should be boiled for ten minutes, but exception must be made in respect of certain dyed fabrics and other special articles; (*b*) all movable textile materials *which cannot be boiled*—including blankets and other

at an end, and final disinfection of the premises is needed.

Disinfection should always be carried out under the direction of the sanitary staff at the end of the case, but disinfectants may be supplied gratuitously by the **S.A.** for use during the illness. Clothing and all movable articles should either be boiled at home, or removed to a disinfecting station and treated by steam or hot air; rooms, and articles that cannot be removed, should be disinfected in the manner described on page 459 (*see* also Chap. xiii.).

When the patient is removed to hospital the premises may be disinfected at once, but the occurrence of any later case will, of course, necessitate a repetition of the process.

Home cases offer more difficulty. The final disinfection cannot usefully take place until after the end of the infectious stage, as determined by the written certificate of the medical attendant or the judgment of the **M.O.H.** It is desirable, in order to prevent misunderstanding, to fix a minimum interval between onset and final disinfection, which in scarlet-fever should not be less than six weeks, and to explain this and the reasons for it upon the printed notices left at the house.

Sanitary defects must be remedied, and any clue or even suspicion as to milk or water infection must be followed up at once. It may be necessary to communicate with employers or other persons, if there is reason to anticipate neglect of due precautions against conveying infection.

In outbreaks of small-pox it is necessary to provide for immediate vaccination or revaccination, and to urge it not only upon the inmates of the infected house, but also upon all who have been in contact with the patient, and upon his neighbours and fellow workmen.

Quarantine, in the original sense, is not

observed in this country The special precautions directed against the importation of infection from abroad are those set forth in the **L.G.B.** Order of November 9th, 1896, summarised below.

Regulations as to cholera, yellow fever, and plague.—Every Port Sanitary Authority, or other **S.A.** within whose district persons are likely to be landed from ships "coming foreign," must appoint a place for mooring such as are infected, and must provide for the reception of cases (actual or suspected) of cholera, yellow fever, or plague. A ship is to be deemed "infected" if there is or has been during the voyage, or during stay in the port of departure or in a port of call, any case of the above-named diseases on board. An infected ship must hoist a black and yellow flag when within three miles of the coast of England or Wales. The Customs Officer, who is the first to board the ship, must as far as possible ascertain whether it is "infected" or not, and if he has reason to believe that it is, or that it has come from an infected port, he must obtain from the master (or from the surgeon if there be one) a written statement in prescribed form declaring the occurrence or non-occurrence of cases or suspected cases during the voyage. If he finds the ship to be infected he must order the master to anchor, and must give notice to the **S.A.** of the port at which the ship is about to call.

If from such warning, or from other information, the **M.O.H.** has reason to believe that any ship within the jurisdiction of his **S.A.** is infected, he must forthwith visit and examine it; and *may* do so if it comes from an infected port. If he finds that there is or has been a case (of one of the three diseases in question) on board, he must certify accordingly to the master, who is thereupon bound to moor in the place appointed. The **M.O.H.** must then examine every person on board, none being allowed to leave the ship until the examination is made. All who are found to be suffering from such disease are to be removed to the hospital or place provided by the **S.A.**, if their condition admit of it, and must not leave such place until the **M.O.H.** certifies that they are free from the disease If they cannot be removed, the ship remains subject to the control of the **M.O.H.**, without whose written consent the infected persons cannot leave the ship. Persons certified by the **M.O.H.** to be suffering from an illness *which he suspects* may prove to be one of the three, *may be detained either* on the ship or in some place provided

by the **S.A.**, for not more than two days, in order that it may be ascertained whether their illness is or is not of the kind suspected. No person, not certified as above, is to be permitted to land, unless he satisfies the **M.O.H.** as to his name, place of destination, and address at such place; and the **M.O.H.** must give such names and addresses to the clerk of the **S.A.**, who must transmit them to the **S.A.** of the districts in question. The **M.O.H.** must give directions and take such steps as may appear to him to be necessary for preventing the spread of infection, and the master of the ship must carry out such directions as are given to him. In the event of a case ending fatally on board, the master must, at the direction of the **S.A.**, either bury the body at sea, properly weighted, or deliver it to the **S.A.** for interment. He must disinfect, and if necessary destroy, the clothing, bedding, and other articles of personal use likely to retain infection, which have been used by infected persons; and disinfect the ship, and disinfect or destroy all articles therein probably infected, according to the directions of the **M.O.H.** If he believes the ship to be infected, or to come from an infected port, the **M.O.H.** may order the bilge water and water ballast to be pumped out before the ship enters dock; or may cause the water-ballast tanks to be sealed, if emptying them would endanger the ship. He may order all casks or tanks containing drinking water to be emptied and cleansed, on the **S.A.** providing a proper supply.

Where a vessel is not infected, but has passengers on board who are in a filthy or otherwise unwholesome condition, the **M.O.H.** may certify to the master that in his opinion it is desirable, with a view to checking the introduction or spread of cholera, yellow fever, or plague, that no persons should be allowed to land until they have satisfied him as to their names and places of destination, and addresses at such place. Thereupon the same measures are to be adopted as in case of persons permitted to leave an infected ship.

The **L.G.B.** have from time to time issued, and subsequently revoked, other Orders (under the powers conferred upon the Board by s. 130 of the Public Health Act of 1875), prohibiting the importation of rags, etc., from infected foreign ports, or requiring that such goods shall be disinfected or destroyed, to the satisfaction of the **M.O.H.**

CHAPTER XVII.

MEDICAL OFFICERS OF HEALTH AND SANITARY INSPECTORS.

Every Sanitary Authority is required (Public Health Act, 1875, secs. 189, 190) to appoint one or more medical officers of health and an inspector of nuisances. Two or more **S.A.** may appoint the same **M.O.H.**; and, apart from this, the **L.G.B.** is empowered (s. 286) compulsorily to unite districts for the purpose of appointing a **M.O.H.** County Councils are authorised, by s. 17 of the Local Government Act, 1888, to appoint (county) medical officers of health, who are forbidden to hold other appointments or engage in private practice without the written consent of the Council.

If any part of the salary of the **M.O.H.** of a local authority is repaid, the **L.G.B.** has the same powers in regard to qualification, appointment, duties, salary, and tenure of office as it has in the case of a Poor Law medical officer (Public Health Act, s. 191).

Qualifications.—The Orders issued by the **L.G.B.** require that the **M.O.H.** shall be registered under the Medical Act of 1858, and be qualified by law to practise both medicine and surgery in England and Wales. The powers of the Board in this respect are practically superseded by the Local Government Act, 1888, s. 18 of which requires that (except when the **L.G.B.**, for reasons brought to their notice, may see fit in particular cases especially to allow) every **M.O.H.** appointed after the passing of the Act shall be legally qualified for the practice of medicine, surgery, and midwifery; and further, by the same section, he must, if appointed after the 1st of *January, 1892,* to a district having at the last

census 50,000 inhabitants or more, appear in the Medical Register as the holder of a diploma in Sanitary Science, Public Health, or State Medicine under s. 21 of the Medical Act, 1886; or have been, during some three consecutive years prior to 1892, a medical officer of a district with a population (according to the last census) of not less than 20,000; or have been for not less than three years a medical officer or inspector of the **L.G.B.**

Tenure of office.—The **L.G.B.** have no control over the tenure of office unless a portion of the salary is repaid to the **S.A.*** If the **M.O.H.** be appointed under the latter condition, he may continue to hold office for such period as the **S.A.** may, with the approval of the **L.G.B.**, determine, or until he die or resign, or be removed by such Authority with the consent of the **L.G.B.**, or by the **L.G.B.** The **S.A.** may suspend him, but must forthwith report their action, together with the cause, to the **L.G.B.**, the latter Board having the power to remove the suspension. If a **S.A.** desire to change the duties or salary of an officer (or any change be made in the extent of the district), and he decline to acquiesce therein, they may give him six months' notice to determine his appointment, but only with the consent of the **L.G.B.**

Salary.—This is only controlled by the **L.G.B.** in cases as above; the salary has then to be approved by the **L.G.B.**, and with the consent of this Board a reasonable compensation may be paid by the Authority on account of extraordinary services or other unforeseen or special circumstances in connection with the duties of the **M.O.H.** or the necessities of the district.

* These contributions, amounting to half the salary, are paid by County Councils on the certificate of the **L.G.B.**, if claimed by the **S.A.**, and if copies of the reports have been duly received by the Board and by the County Council.

Duties.—The duties of medical officers of health as prescribed by the **L.G.B.** are the same whether a contribution is made to the salary or not, except that in the latter case the officer is obliged to report his appointment within seven days to the **L.G.B.**

The following duties are prescribed by the Board's Order of March, 1891, for every medical officer of health appointed or reappointed after that date:—

(1) He shall inform himself as far as practicable respecting all influences affecting, or threatening to affect, injuriously the public health within the district.

(2) He shall inquire into and ascertain by such means as are at his disposal the causes, origin, and distribution of diseases within the district, and ascertain to what extent the same have depended on conditions capable of removal or mitigation.

(3) He shall, by inspection of the district, both systematically at certain periods, and at intervals as occasion may require, keep himself informed of the conditions injurious to health existing therein.

(4) He shall be prepared to advise the **S.A.** on all matters affecting the health of the district, and on all sanitary points involved in the action of the **S.A.**; and in cases requiring it he shall certify for the guidance of the **S.A.** or of the justices as to any matter in respect of which the certificate of a **M.O.H.** or a medical practitioner is required as the basis or in aid of sanitary action.

(5) He shall advise the **S.A.** on any question relating to health involved in the framing and subsequent working of such byelaws and regulations as they may have power to make, and as to the adoption by the **S.A.** of the Infectious Disease (Prevention) Act, 1890, or of any section or sections of such Act.

(6) On receiving information of the outbreak of any contagious, infectious, or epidemic disease of a dangerous character within the district, he shall visit the spot without delay, and inquire into the causes and circumstances of such outbreak, and in case he is not satisfied that all due precautions are being taken, he shall advise the persons competent to act as to the measures which may appear to him to be required to prevent the extension of the disease, and take such measures for the prevention of the disease as he is legally authorised to take under any statute in force in the district, or by any resolution of the **S.A.**

(7) *Subject to* the instructions of the **S.A.**, he shall direct

or superintend the work of the inspector of nuisances in the way and to the extent that the S.A. shall approve, and on receiving information from the inspector of nuisances that his intervention is required in consequence of the existence of any nuisance injurious to health, or of any overcrowding in a house, he shall, as early as practicable, take such steps as he is legally authorised to take under any statute in force in the district, or by any resolution of the S.A., as the circumstances of the case may justify and require.

(8) In any case in which it may appear to him to be necessary or advisable, or in which he shall be so directed by the S.A., he shall himself inspect and examine any animal, carcase, meat, poultry, game, flesh, fish, fruit, vegetables, corn, bread, flour, or milk, and any other article to which the provisions of the Public Health Act, 1875, in this behalf shall apply, exposed for sale, or deposited for the purpose of sale, or of preparation for sale, and intended for the food of man, which is deemed to be diseased, or unsound, or unwholesome, or unfit for the food of man; and if he finds that such animal or article is diseased, or unsound, or unwholesome, or unfit for the food of man, he shall give such directions as may be necessary for causing the same to be dealt with by a justice according to the provisions of the statutes applicable to the case.

(9) He shall perform all the duties imposed upon him by any byelaws and regulations of the S.A., duly confirmed, where confirmation is legally required, in respect of any matter affecting the public health, and touching which they are authorised to frame byelaws and regulations.

(10) He shall inquire into any offensive process of trade carried on within the district, and report on the appropriate means for the prevention of any nuisance or injury to health therefrom.

(11) He shall attend at the office of the S.A., or at some other appointed place, at such stated times as they may direct.

(12) He shall from time to time report in writing to the S.A. his proceedings, and the measures which may require to be adopted for the improvement or protection of the public health in the district. He shall in like manner report with respect to the sickness and mortality within the district, so far as he has been enabled to ascertain the same.

(13) He shall keep a book or books, to be provided by the S.A., in which he shall make an entry of his visits, and notes of his observations and instructions thereon, and also the date and nature of applications made to him, the date and result of the action taken thereon, and of any action taken on previous

reports; and shall produce such book or books, whenever required, to the **S.A.**

(14) He shall also make an annual report to the **S.A.** up to the end of December in each year, comprising a summary of the action taken, or which he has advised the **S.A.** to take, during the year for preventing the spread of disease, and an account of the sanitary state of his district generally at the end of the year. The report shall also contain an account of the inquiries which he has made as to conditions injurious to health existing in his district, and of the proceedings in which he has taken part or advised under any statute, so far as such proceedings relate to those conditions, and also an account of the supervision exercised by him, or on his advice, for sanitary purposes, over places and houses that the **S.A.** have power to regulate, with the nature and results of any proceedings which may have been so required and taken in respect of the same during the year. It shall also record the action taken by him, or on his advice, during the year, in regard to offensive trades, to dairies, cowsheds, and milkshops, and to factories and workshops. The report shall also contain tabular statements (on forms to be supplied by the **L.G.B.** or to the like effect) of the sickness and mortality within the district, classified according to diseases, ages, and localities. Provided that if the **M.O.H.** shall cease to hold office before December 31st in any year, he shall make the like report for so much of the year as shall have expired when he ceases to hold office.

(15) He shall give immediate information to the **L.G.B.** of any outbreak of dangerous epidemic disease within the district, and shall transmit to the Board a copy of each annual report and of any special report. He shall make a special report to the **L.G.B.** of the grounds of any advice he may give to the **S.A.** with a view to the closure of any school or schools, in pursuance of the Code of Regulations approved by the Education Department, and for the time being in force.

(16) At the same time that he gives information to the **L.G.B.** of the outbreak of infectious disease, or transmits to them a copy of his annual or any special report, he must give the like information, or transmit a copy of such report, to the County Council of the county in which his district is situated.

(17) In matters not specifically provided for in this Order he shall observe and execute any instructions issued by the **L.G.B.**, and the lawful orders and directions of the **S.A.** applicable to his office.

(18) Whenever the **L.G.B.** shall make regulations for all *or any of the* purposes specified in s. 134 of the Public

Health Act, 1875, and shall declare the regulations so made to be in force within any area comprising the whole or any part of the district, he shall observe such regulations, so far as the same relate to or concern his office.

The duties of the medical officer of health to a Port S.A. are defined by the L.G.B. in terms which are closely parallel to those given above, omitting the references to regulated trades and inspection of food, and substituting "ships" for "houses," and "shipping within the district" for "district."

"He shall inform himself as far as practicable respecting all conditions affecting or threatening to affect injuriously the health of crews and other persons on ship-board within the district . . . . . He shall inquire into and ascertain by such means as are at his disposal, the causes, origin, and distribution of diseases in the ships and other vessels within the district, and ascertain to what extent the same have depended on conditions capable of removal or mitigation . . . . . He shall, by inspection of the shipping in the district, keep himself informed of the condition injurious to health existing therein . . . . . On receiving information of the arrival within the district of any ship having any infectious or epidemic disease of a dangerous character on board, or of the outbreak of any such disease on board any ship within the district, he shall visit the vessel without delay, and inquire into the causes and circumstances of such outbreak, and advise the persons competent to act as to the measures which may appear to him to be required to prevent the extension of the disease, and so far as he may be lawfully authorised to assist in the execution of the same . . . . . On receiving information from the Inspector of Nuisances that his intervention is required in consequence of the existence of any nuisance injurious to health, or of any overcrowding in a ship, he shall, as early as practicable, take such steps authorised by the Public Health Act, 1875, on that behalf, as the circumstances of the case may justify and require . . . . . . When any vessel within his district has had dangerous infectious disease on board, he shall give notice thereof to the M.O.H. of any port within the United Kingdom whither such vessel is about to *sail.*"

The substance of Clauses 4, 5 (omitting the reference to the Infectious Disease Prevention Act), 9, 11,

12, 13, 14 (omitting the reference to trades, etc.), 15 (omitting the reference to schools), 17, and 18, of the duties of **M.O.H.,** is applicable to Port **M.O.H.,** *mutatis mutandis.*

The statutory duties of county medical officers of health have not yet been authoritatively defined.

Annual reports.—The following instructions have been issued by the **L.G.B.** :—

Every **M.O.H.,** appointed under Order of the **L.G.B.,** is required to make an annual report with regard to each sanitary district, or division of a district, which is under his superintendence. This report is to be for the year ending the 31st of December, or, if the officer at that date has not been in office for a whole year, then for so much of the year as has elapsed since his appointment. The report is to be made to the Council by whom he is appointed, and the **M.O.H.** himself should send a copy of it to the **L.G.B.** and to the County Council or County Councils of the county or counties within which his district may be situated. It should be made as soon as practicable after the expiration of the year to which it relates. The **M.O.H.** ought not, in general, to have any difficulty in doing this within a month or six weeks, but if from any special circumstances the report cannot be completed within six weeks, it should be understood that the delay must not be indefinite, and that the report should be in the hands of his Council, and of the Board, within, at most, three months from the end of the year. Any special circumstances preventing the delivery of the Board's copy within two months from the end of the year should at once be reported to the Board. The Board's copy of the report should be forwarded to them when the original is sent to the Council, except where the report is likely to be printed by order of the Council. In such cases the Board need only be supplied with a printed copy. It is very desirable that the annual report should be printed, for the sake of facility of reference and in order that a supply of copies may be available for distribution among the Town or District Councillors and other persons interested

Article 18 (s. 14, of the Board's Order of March, 1891, respecting the duties of the **M.O.H.,** specifies the information to be contained in the annual report

The report should be chiefly concerned with the conditions affecting health in the district and with the means for improving those *conditions.* It should contain an account, brought

up to the end of the year under review, of the sanitary circumstances of the district, and of any improvement or deterioration in these circumstances which may have occurred during the year. Care should be taken to report fully and explicitly on the influences affecting or threatening to affect injuriously the public health in the district, and on the action which has been taken, or which may still be needed, with a view to combat those influences. It is of especial importance that the M.O.H. should record what action has been taken to remedy unhealthy conditions which have been reported by him in previous annual reports, or in special reports presented during the year under review, and that attention should be called afresh, year by year, to such as remain unremedied.

As subjects concerning which the Board desire to obtain, through annual reports of the M.O.H., not only definite general information, but record also of particular changes of condition that may have occurred incidentally or by action of the local authority, the following deserve to be especially borne in mind:—*

Physical features and general character of the district.

House accommodation, especially for the working classes: its adequacy and fitness for habitation. Sufficiency of open space about houses, and cleanliness of surroundings. Supervision over erection of new houses.

Sewerage and drainage: its sufficiency in all parts of the district. Condition of sewers and house drains. Method or methods of disposal of sewage. Localities where improvements are needed.

Excrement disposal: system in vogue; defects, if any.

Removal and disposal of house refuse—whether by public scavenger or occupiers: frequency and method.

Water supply of the District or its several parts: its source (from public service or otherwise), nature (river water, well water, upland water, etc.), sufficiency, wholesomeness, and freedom (by special treatment or otherwise) from risks of pollution.

Places over which the Council have supervision, *e.g.*, lodging-houses, slaughterhouses, dairies, cowsheds, and milkshops, bakehouses, factories and workshops, and offensive trades.

* This list is, of course, not exhaustive. Additional details are:—Common lodging-houses, tenement-houses, back-to-back houses; House drainage and connections; Industries of the district; River pollution by sewage and trade effluents; Burial grounds; Adoptive acts, byelaws and regulations in force; Action taken under the above, and under the Sale of Food and Drugs Acts; the Housing of the Working Classes Acts; Canal Boats Act; Meteorological data; Prevalence of epizootic or epiphytic disease; Vaccination (latest available returns); Legal proceedings.

Nuisances: proceedings for their abatement: any remaining unabated.

Methods of dealing with infectious diseases: notification; isolation; hospital accommodation and its sufficiency; disinfection.

With regard to such points it should be remembered that these reports are for the information of the Board and of the County Council as well as of the Council of the district, and that a statement of the local circumstances and a history of local sanitary questions which may seem superfluous for the latter may often be needed by the former bodies.

Section 132 of the Factory and Workshop Act, 1901, requires that:

"The **M.O.H.** of every District Council shall, in his annual report to them, report specifically on the administration of this Act in workshops and workplaces, and he shall send a copy of his annual report, or so much of it as deals with this subject, to the Secretary of State."

The copy should be addressed to the Secretary of State, Home Office, Whitehall, and the foregoing remarks with respect to the transmission of the report to the **L.G.B.** apply also to its transmission to the Home Office.

The **M.O.H.** is required to report on the administration of the Factory and Workshop Act, 1901, only in so far as this administration is in the hands of the District Council and is concerned with matters in his department. In reporting on the sanitary administration of workshops and workplaces he should include an account of the action with respect to factories, workshops, and workplaces taken under the Public Health Acts as well as under the Factory and Workshop Act.

In reporting on the sanitary condition of workshops and workplaces the **M.O.H.** should state what action has been taken to remedy any defective conditions met with under each heading. He should state whether s. 22 of the Public Health Acts (Amendment) Act, 1890, is in force in the district, and what standard of "sufficiency and suitability" of sanitary accommodation is adopted locally.

As regards bakehouses, s. 101, Factory and Workshop Act, 1901, forbids the use after 1st January, 1904, of any underground bakehouse, *i.e.* any room used for baking or for any process incidental thereto, so situate that the surface of the floor is more than three feet below the surface of the footway of the adjoining street, or of the ground adjoining or nearest to the room, unless, in the case of an underground bakehouse so used at *the passing of the Factory and Workshop Act, 1901, the District Council* are satisfied that it is suitable for the pur-

pose as regards construction, light, ventilation, and in all other respects, and have given a certificate of its suitability. It is desirable that the **M.O.H.** should record how many such certificates of suitability have been given by the District Council, and what were the conditions required to be complied with in the granting of such certificates.

The **M.O.H.**, in reporting his proceedings and advice, should put on record whether he has made systematic inspections of his district. By "systematic inspections" are meant inspections independent of such inquiries as the **M.O.H.** may have to make into particular outbreaks of disease, or into unwholesome conditions to which his attention has been specially called by complaints or otherwise; and such inspections will include the house-to-house inspections which may be necessary in particular localities.

In making systematic inspections, as in much of his other action, the **M.O.H.** will usually have required the assistance of the Inspector of Nuisances; and the Medical Officer should include in his report an account of the action which, at his instance, the Inspector may have taken for the removal of nuisances injurious to health.

The report should deal with the extent, distribution, and causes of disease, especially of epidemic and notifiable diseases, within the district; and should give an account of any noteworthy outbreaks of such diseases during the year under review, stating the result of his investigations into their origin and propagation, and the steps taken by him, or on his advice, with a view to check their spread.

The tabular statements of sickness and mortality in the district during the year, to be made on the forms supplied for the purpose, should be the subject of comment in the text of the report, in so far as deductions from them may assist the Board and the Councils concerned to an appreciation of the lines of action needful in the future.

Sources of information.—*Returns of registered deaths* should be obtained weekly from each of the registration sub-districts within the area.* These

* "Every registrar, when and as required by a **S.A.** . . . . shall transmit by post or otherwise a return, certified under the hand of such registrar to be a true return, of such of the particulars registered by him concerning any death as may be specified in the requisition of the **S.A.** The **S.A.** may supply a form of the prescribed character, for the purpose of the return, and in that case the return shall be made in the form so supplied. The registrar making such returns shall be entitled to a fee of twopence, and to a further fee of twopence for every death entered in such return, which fee shall be paid by the Authority requiring the return." (*Births and Deaths Registration Act*, 1874, *s.* 28.)

returns should give, as regards every death registered during the week, the name, age, sex, residence, and occupation of the deceased, the nature and duration (so far as stated on the certificate of cause of death) of each primary and secondary cause of death, and the name of the certifying practitioner. "Immediate notice should be given of all deaths from infectious disease in fresh localities, and all groups of deaths from such disease, or from diarrhœa, in any localities" (**L.G.B.** *Memorandum, dated June*, 1882). A fee of twopence for each return and twopence for each entry is payable by the Authority. Returns should also be obtained from the registrars, at weekly, monthly, or quarterly intervals, of the births registered in such intervals; these returns should distinguish between males and females, and between legitimate and illegitimate births. Deaths of non-residents in the locality must, of course, be distinguished from the rest, and the necessary indications for this purpose should be given in the returns. Arrangements must be made separately for information of the deaths in distant public institutions of residents in the locality.

Notification returns. Compulsory notification of certain infectious diseases, voluntary notification of others, notification from schools, etc., all furnish the Medical Officer with information respecting the occurrence of such disease.

Returns of pauper sickness.—An order of the **L.G.B.**, dated February 12th, 1879, requires all district and workhouse medical officers appointed after February 28th, 1879, to furnish the **M.O.H.** with returns of pauper sickness and deaths, and to notify the outbreak of any dangerous infectious disease. The same is required (by an order dated June 14th, 1879) of medical officers of district schools appointed after June 24th, 1879. The Guardians should be asked to instruct

their clerk to copy from the district medical officer's relief lists the new cases which are reported at each meeting of the Guardians, and to forward the same promptly and regularly to the **M.O.H.**, and to instruct the Poor Law medical officers to give to the **M.O.H.** the earliest possible information of cases of dangerous infectious disease under their charge.

Cases of dangerous infectious diseases occurring on canal boats or in common lodging-houses must be reported to the **M.O.H.**, and the **S.A.** have power to make byelaws requiring notification of such diseases in "tenement" lodging-houses, and in vans or tents.

Maps.—A good map is essential. It should show the boundaries of the district, and of each of its subdivisions (whether parishes, townships, registration sub-districts, special drainage districts, or other) which have a bearing upon sanitary administration, and also the main sewers and water-mains. Maps showing the geology of the district, the contour lines, and the different watersheds, should be obtained, if possible. Maps showing the local distribution of disease and mortality have already been referred to.

Periodical reports, etc.—The annual and quarterly reports of the Registrar-General are indispensable. The annual summaries and weekly returns deal only with the statistics of the large towns. Reports of the inspectors of the **L.G.B.** affecting any part of the district should, of course, be obtained.

Acts of Parliament.—In addition to any local Acts in force in the district, and all the chief statutes dealing with public health, the **M.O.H.** should be familiar with any other Acts which the special circumstances of his district may render important, *e.g.* the Alkali Act.*

* Lumley's or Glen's Public Health Acts, Glen's L.G.B. *Sanitary Orders*, and the *Model Byelaws of the* L.G.B. are valuable for reference.

Byelaws and regulations.—The byelaws and regulations in force in the district can readily be obtained, and are not less important than the preceding.

Census data.—The **M.O.H.** should be in possession of all the information regarding his district given by each census taken since its formation. Arrangements should, if possible, be made at the time when the census is taken to obtain a record of the particulars regarding each "enumeration district" for the use of the **S.A.**

It is desirable to keep registers showing for each village or hamlet the dates and particulars of every death, and of every notified case of infectious disease. In towns this would take the form of a "street and house register." If cases of disease as well as deaths are entered, they may be distinguished by red ink. Registers of notified diseases have already been referred to. Registers of all deaths occurring among certain trades will greatly facilitate any future investigation which the **M.O.H.** may have to make into the influence of those trades upon mortality.

The seemingly formidable records mentioned above, if well arranged in the first instance, and systematically kept, involve much less labour than would appear at first sight. They are invaluable in inquiries regarding the incidence of mortality and disease upon any given locality or occupation, and materially simplify the preparation of the annual report.

Auxiliary agencies.—In addition to the routine work of the **M.O.H.** there are many auxiliary agencies which may be established in his district or by his **S.A.** which call for more or less of his attention; such, for example, are voluntary health societies, crêches, infant milk depôts, bacteriological work, chemical analysis, meteorological apparatus, reception houses for infectious "contacts," baths for cleansing of verminous persons, etc.

Infants' Milk Depôts.—Infantile mortality, as we have seen, bears a definite relationship to (*a*) the feeding of infants, (*b*) personal care of infants by parents, (*c*) urban life, and (*d*) certain meteorological conditions affecting temperature and the dissemination of dust. Other elements enter into the problem, but, so far as municipal action is concerned, those are the four main elements. The problem, in practice, is largely one of polluted milk. The sources of the pollution are not only in unsatisfactory methods of milking, and in storing and conveying the milk supplied, but also in dirty domestic conditions, and particularly in carelessness in the use of feeding bottles. The ideal is breast-feeding, and in respect of the artificial feeding of infants a pure modified milk supply which needs no sterilisation; and towards that end our efforts should be directed. The best possible under existing conditions involves sterilisation or pasteurisation, modification, and protection from home contamination. Such a milk supply should be under medical supervision and adopted only in suitable cases.

It would appear that there are five possible means of supplying a suitable and pure milk for infants—(1) By means of Municipal Milk Depôts similar to institutions at Nancy and Fécamp; (2) By one or more dairymen undertaking to furnish such modified milk (certified) under medical supervision; (3) By obtaining such a supply from some central source; (4) By means of medical "milk commissions," as in the United States; or (5) By means of a voluntary society supplying such milk under necessary supervision and control.

The French depôts are, broadly speaking, of two types, the "consultation de nourrissons," as at Nancy, and the "goutte de lait," as at Fécamp. The latter is the prototype of the infants' milk depôts established in this country at Liverpool, Battersea, and elsewhere, to succour those infants of the poor for whom breast-feeding is practically impossible. The milk is modified, pasteurised, or sterilised, and served in "one-feed" bottles, the amount and kind of modification depending, of course, upon the age of the infant. It is too early to speak of the effect such milk depôts exert upon infant mortality, but there can be no question of their value if properly controlled. It is, of course, essential that the milk should be derived from healthy clean cows, and all the dairying carried out on hygienic principles.

Bacteriological Laboratories.—The great value of early and accurate diagnosis in such diseases as tuberculosis, diphtheria, anthrax, enteric fever, and the bacteriological investigation of water, milk, cheese, of sewage and its effluents, of air, etc., has now become generally recognised, with the result that a Public Health

Department is not considered fully equipped unless it is provided with facilities for bacteriological research, either by establishing a municipal laboratory or by utilising a private laboratory such as those in connection with hospitals and medical schools. Facilities should be provided for the free examination of any materials from infectious cases submitted by medical men.

Duties of sanitary inspectors.—The work of the Sanitary Inspector (or "Inspector of Nuisances") is closely connected with that of the **M.O.H.**, but the broad lines separating them will be apparent from the following definition of the inspector's duties, formulated by the **L.G.B.**

"(1) He shall perform, either under the special directions of the **S.A.**, or (so far as authorised by the **S.A.**) under the directions of the **M.O.H.**, or, in cases where no such directions are required, without such directions, all the duties specially imposed upon an Inspector of Nuisances by the Public Health Act, 1875, or by any other statute or statutes, or by the Orders of the **L.G.B.**, so far as the same apply to his office.

"(2) He shall attend all meetings of the **S.A.** when so required.

"(3) He shall, by inspection of the district, both systematically at certain periods, and at intervals as occasion may require, keep himself informed in respect of the nuisances existing therein that require abatement.

"(4) On receiving notice of the existence of any nuisance within the district, or of the breach of any byelaws or regulations made by the **S.A.** for the suppression of nuisances, he shall, as early as practicable, visit the spot, and inquire into such alleged nuisance or breach of byelaws or regulations.

"(5) He shall report to the **S.A.** any noxious or offensive businesses, trades, or manufactories established within the district, and the breach or non-observance of any byelaws or regulations made in respect of the same.

"(6) He shall report to the **S.A.** any damage done to any works of water supply, or other works belonging to them, and also any case of wilful or negligent waste of water supplied by them, or any fouling, by gas, filth, or otherwise, of water used for domestic purposes.

"(7) He shall from time to time, and forthwith upon

complaint, visit and inspect the shops and places kept or used for the preparation or sale of butcher's meat, poultry, fish, fruit, vegetables, corn, bread, flour, milk, or any other article to which the provisions of the Public Health Act, 1875, in this behalf shall apply, and examine any animal, carcase, meat, poultry, game, flesh, fish, fruit, vegetables, corn, bread, flour, milk, or other article as aforesaid, which may be therein; and in case any such article appear to him to be intended for the food of man, and to be unfit for such food, he shall cause the same to be seized, and take such other proceedings as may be necessary in order to have the same dealt with by a Justice: provided that in any case of doubt arising under this clause, he shall report the matter to the M.O.H., with the view of obtaining his advice thereon.

"(8) He shall, when and as directed by the S.A., procure and submit samples of food, drink, or drugs, suspected to be adulterated, to be analysed by the analyst appointed under the Sale of Food and Drugs Act, 1875, and upon receiving a certificate stating that the articles of food, drink, or drugs are adulterated, cause a complaint to be made, and take other proceedings prescribed by that Act.

"(9) He shall give immediate notice to the M.O.H. of the occurrence within the district of any contagious, infectious, or epidemic disease; and whenever it appears to him that the intervention of such officer is necessary, in consequence of the existence of any nuisance injurious to health, or of any overcrowding in a house, he shall forthwith inform the M.O.H. thereof.

"(10) He shall, subject to the directions of the S.A., attend to the instructions of the M.O H. with respect to any measures which can be lawfully taken by an Inspector of Nuisances under the Public Health Act, 1875, or under any statute or statutes, for preventing the spread of contagious, infectious, or epidemic disease of a dangerous character.

"(11) He shall enter from day to day, in a book provided by the S.A., particulars of his inspections, and of the action taken by him in the execution of his duties. He shall also keep a book or books, to be provided by the S.A., so arranged as to form as far as possible a continuous record of the sanitary condition of each of the premises in respect of which any action has been taken under the Public Health Act, 1875, or under any other statute or statutes, and shall keep any other systematic records that the S.A. may require.

"(12) He shall, at all reasonable times, when applied to by the M.O.H., produce to him his books, or any of them, and render to him such information as he may be able to furnish

with respect to any matter to which the duties of Inspector of Nuisances relate.

"(13) He shall, if directed by the **S.A.** to do so, superintend and see to the due execution of all works which may be undertaken under their direction for the suppression or removal of nuisances within the district.

"(14) He shall, if directed by the **S.A.** to do so, act as Officer of the said Authority as Local Authority under the Contagious Diseases (Animals) Act, 1886, and any Orders or Regulations made thereunder.

"(15) In matters not specially provided for in this Order, he shall observe and execute all the lawful orders and directions of the **S.A.**, and the Orders of the **L.G.B.**, which may be hereafter issued, applicable to his office."

The above statement of duties is general, and the details must be sought in the Acts, Orders, Bye-laws, and Regulations, and in the instructions of the **S.A.** It is competent for the **S.A.** to specialise the work of the Sanitary Inspectors (*e.g.* inspection of meat, inspection of workshops), or to appoint women in that capacity.

CHAPTER XVIII.

SANITARY LAW.

UNDER this heading it is proposed to give a summary of the principal Acts of Parliament bearing upon public health in general, reserving for consideration in later chapters industrial legislation and local bye-laws.

As elsewhere in this volume, **S.A.** stands for Sanitary Authority, **L.G.B.** for Local Government Board, and **M.O.H.** for Medical Officer of Health.

Public Health Act, 1875.—The whole of England and Wales, except London, consists of Urban and Rural Sanitary Districts, under the jurisdiction respectively of Urban and Rural **S.A.'s** (s. 5), which, in pursuance of the Local Government Act of 1894, are now termed Urban and Rural District Councils. That portion of the area of a Union which is not included in any Urban District constitutes a Rural Sanitary District, and the guardians representing that part of the union are the Rural **S.A.** (s. 9).

Sewers, except certain private sewers, are vested in the **S.A.** of the district (s. 13). The **S.A.** may purchase (s. 14) or construct (s. 15) sewers. They must provide such sewers as are necessary for effectually draining their district (s. 15). Powers are given by s. 27 for the treatment and disposal of sewage. The sewers must be so constructed, covered, ventilated, and kept as not to be a nuisance or injurious to health, and must be properly cleansed (s. 19).

House drainage.—If any house is without a sufficient drain the **S.A.** *must* require the owner or occupier to provide a drain, and may prescribe the materials, size, and levels. This drain must lead to

the public sewer if there be any within 100 feet of the site of the house, if not, to a covered cesspool in such position (not under a house) as the **S.A.** may direct. Failing compliance, the Authority may carry out the works. No house in an urban district must be built or occupied until proper covered drains have been constructed to the satisfaction of the **S.A.** The **S.A.** may make regulations as to the mode in which connections between drains and sewers are to be made. Upon giving due notice, and complying with such regulations, the owner of any premises is entitled to carry drains into the public sewers (sections 21–25).

Excrement and refuse disposal.—It is unlawful to erect any house without a sufficient water-closet, earth closet, or privy, and an ashpit with proper doors and coverings, and the same must be provided for any existing house on the order of the **S.A.**, who may require a separate closet for each house (sections 35–36). The **S.A.** may order the provision of separate closets for each sex in factories and workshops where both sexes are employed (s. 38); this applies also to above-ground parts of coal-mines if women and girls are employed (Coal Mines Regulation Act, 1872, s. 74)—the corresponding parts (pit-banks) of metalliferous mines are factories or workshops. Urban **S.A.'s** may provide public closets, urinals, or receptacles for refuse (sections 39, 45). Every **S.A.** must see that all drains, closets, ashpits, and cesspools are properly constructed and kept (s. 40).

On written complaint that any drain, closet, ash-pit, or cesspool is a nuisance, the **S.A.** may authorise their officer to enter the premises (after giving twenty-four hours' notice, except in case of emergency) and open the ground; if any defect is found, the **S.A.** must serve notice upon the owner or occupier, but if there be no defect, the **S.A.** must close the ground and make good any damage.

Scavenging and cleansing.—The **S.A.** *may*, and when required by order of the **L.G.B.** *shall*, themselves undertake or contract for the removal of house refuse, the cleansing of earth-closets, privies, ashpits, and cesspools, and cleansing of streets (s. 42). In that case they are liable to penalty for any delay exceeding seven days after written notice from any householder.

Cleansing of Houses.—If the **M.O.H.** or two medical practitioners certify that any house or part thereof is so filthy as to endanger health, or that the whitewashing, cleansing, or purifying thereof would tend to prevent infectious disease, the **S.A.** may require the owner or occupier to cleanse, etc., and in his default may themselves do what is necessary (s. 46).

It is unlawful in an urban district to keep swine in any dwelling-house, or so as to be a nuisance, or to suffer any waste water to remain within any dwelling-house for twenty-four hours after written notice from the **S.A.**, or to allow the contents of any water-closet, privy, or cesspool to overflow or soak therefrom. In case of default, the **S.A.** must abate such nuisance (s. 47).

An inspector of nuisances in an urban district may give notice to the owner of any accumulation of offensive matter, or to the occupier of the premises whereon it exists, and if not removed within twenty-four hours, it becomes vested in the **S.A.** to be disposed of by them (s. 49). An urban **S.A.** may give public notice requiring the periodical removal of manure or other refuse matter from stables or other premises and enforce the same under penalty (s. 50).

Water supply.—Any **S.A.** may * construct works for supplying any part of their district with water;

* The wording here is permissive; but see pages 498-499.

or may hire or purchase such works, or contract for a supply (s. 51); and may require houses to be supplied with water when they are without a proper supply, if it can be furnished at a cost not exceeding the water-rate authorised by any local Act, or twopence a week, or such other cost as the **L.G.B.** may, upon application, determine to be reasonable in the circumstances (s. 62).

Heavy penalties are incurred by persons polluting any stream, pond, etc., with gas washings (s. 68), and a local authority may proceed against anyone polluting any watercourse with sewage (s. 69). A Justice's order may be obtained for the closing of a well or cistern the water of which is used, or likely to be used, for drinking or domestic purposes, when the water is so polluted as to be injurious to health, and the Court may cause the water to be analysed at the cost of the **S.A.** (s. 70).

Cellar dwellings.—No cellar built or rebuilt since 1848 (the date of a previous Act) can be separately occupied as a dwelling, nor any cellar whatever, unless it comply with the following requirements

(*a*) The height must in every part be at least seven feet, three feet of which must be above the level of the adjoining street. (*b*) An open area at least $2\frac{1}{2}$ feet wide in every part, and 6 in. below the level of the floor, must extend along the whole frontage. It may be crossed by steps, but not opposite the window. (*c*) The cellar must be drained by a drain at least 1 foot below the floor. (*d*) There must be proper closet and ashpit accommodation. (*e*) There must be a fireplace and chimney and (*f*) a window at least 9 square feet in area, made to open. The window of a back cellar let or occupied along with a front cellar need only be 4 square feet in area (sections 71–73).

Anyone passing the night in a cellar is deemed to occupy it (s. 74).

*Common lodging-houses.**—The **S.A.** are required to keep a register of common lodging-houses, and to make byelaws in respect of them (sections 76–80). It is unlawful to keep a common lodging-house unless it be registered (s. 77), and this can only be done after it has been inspected and approved (s. 78). The keeper when required is to affix notice of registration to the house.

When the lodging-house is without a proper supply of water, and this can be furnished at a reasonable rate, the **S.A.** may enforce it (s. 81). The keeper is required to limewash the walls and ceilings in the first week of April and October of every year (s. 82). The **S.A.** may require the keeper of a house in which beggars or vagrants are received, to make returns of persons who have slept there the previous night (s. 83), and the keeper must always give notice to the **M.O.H.** and to the Relieving Officer of any case of infectious disease (s. 84).

Houses let in lodgings.—Any **S.A.** may make byelaws respecting houses let in lodgings or occupied by members of more than one family (s. 90, modified by s. 8 of the Housing of the Working Classes Act, 1885).

Nuisances.—(s. 91.) The following are nuisances. (1) Any premises† in such a state as to be a nuisance or injurious to health. (2) Any pool, ditch, gutter, watercourse, privy, urinal, cesspool, drain,‡ or ashpit, so foul or in such a state as to be

* Lodging-houses in which persons of the poorer class are received for short periods, and, though strangers to each other, are allowed to inhabit one common room. The term does not cover inns, or lodgings let to the middle or upper classes. In London there are Common Lodging Houses *Acts*, 1851-3, in force, incorporating similar powers.

† Including *buildings* or *lands*.

‡ " 'Drain' means any drain of and used for the drainage of one building only, or premises within the same curtilage . . . ." A sewer is a drain receiving the drainage of two or more buildings.

a nuisance or injurious to health. (3) Any animal so kept as to be a nuisance or injurious to health. (4) Any accumulation or deposit which is a nuisance or injurious to health.* (5) Any house,† or part of a house, so overcrowded as to be dangerous or injurious to the health of the inmates, whether or not members of the same family.‡ (6) Any workshop, work-place, or domestic factory, not kept in a cleanly state, or not ventilated in such a manner as to render harmless as far as practicable any gases, vapours, dust, or other impurities generated in the course of the work carried on therein that are a nuisance or injurious to health, or so overcrowded as to be dangerous or injurious to the health of those employed therein.§ (7) Any fireplace or furnace which does not, as far as practicable, consume the smoke arising from the combustible used therein, and which is used for working engines by steam, or in any manufacturing or trade process whatever, and any chimney (not being the chimney of a private dwelling-house) sending forth black smoke in such quantity as to be a nuisance.‖

* There is no penalty if the accumulation or deposit is necessary for, and has not been kept longer than is necessary for the carrying on of any business or manufacture, and if the best available means have been taken for preventing injury to the public health.

† Including schools, and also workshops and other buildings in which persons are employed. *Domestic factories* also are included.

‡ It is customary to adopt the standards of the Model Byelaws, viz. 300 cubic feet per head, counting two children as one adult; but for workshops and work places, see p. 449. In the event of a second conviction for overcrowding within three months, the Court may order the closing of the premises for any period (section 109).

§ The provisions of this subsection apply to all buildings, including schools, factories, and workshops, except such as are subject to the special provisions, relating to cleanliness, ventilation, or overcrowding, of the Factory and Workshop Act.

‖ There is no penalty if the Court is satisfied that such fireplace or furnace is constructed in such manner as to consume as far as practicable, having regard to the nature of the manufacture or trade, all smoke arising therefrom, and that such fireplace or furnace has been carefully attended to by the *person* having the charge thereof.

Later Acts have extended this definition. Thus workshops or workplaces not kept free from effluvia arising from any drain, closet, or other nuisance (Factory Act 1902, s. 2); workshops in any room of which sufficient ventilation is not provided and maintained, or in which the processes carried on render the floor wet, and the floor is not adequately drained (Factory Act, s. 78—*see also* p. 547); tents or vans so filthy or overcrowded as to be a nuisance or injurious to health (Housing Working Classes Act, 1885, s. 9), and unfenced quarries (Quarry Fencing Act, 1887, s. 3) or unfenced shafts of disused metalliferous mines (Metalliferous Mines Regulation Act, 1872, s. 13) within 50 yards of a highway, are nuisances under s. 91, 1875.

Procedure in respect of nuisances.—It is (1) the duty of the **S.A.** to cause to be made from time to time an inspection of their district, to ascertain what nuisances exist, but (2) the **S.A.** may be put in motion by any person aggrieved, or by any two householders or by any officer of the **S.A.**, or by the Relieving Officer, or by any officer of the police. (3) If satisfied as to the existence of a nuisance, the **S.A.** must serve a notice on the person responsible, or if he cannot be found, on the owner or occupier, requiring him to abate it, and to execute such works and do such things as may be necessary. Where the nuisance arises from the want or defect of any structural convenience, or where there is no occupier, notice must be served on the owner. If the person causing the nuisance cannot be found, and the owner or occupier is not responsible, the local authority may abate the nuisance. (4) If the person on whom the notice is served fails to comply, or if the nuisance, although abated, is likely to recur, the **S.A.** may apply to a Justice, who shall summon the person responsible, and may make an order requiring compliance or prohibiting the recurrence of the nuisance, and directing the execution of any works necessary. The Court may further impose a penalty (sections 92—96). Where the nuisance is such as to render the house

unfit for habitation, the Court may order the house to be closed, and may rescind this by a further order when satisfied that the house has been made fit for habitation (s. 97). Any person not obeying the order of the Court, or failing to use due diligence, is liable to penalty; and the **S.A.** may carry out the order and charge him with the expenses (s. 98). Where the person responsible for the nuisance cannot be found, the order of the Court may be executed by the **S.A.** Any matter or thing removed by the **S.A.** in abating any nuisance may be sold. Where a nuisance within a district is caused by some act or default beyond its limits, the **S.A.** may, nevertheless, institute proceedings (s. 108).

Ships.—Any ship or vessel lying in any water within the district of any **S.A.** is subject to their jurisdiction, as if it were a house.* If in any other water, it is deemed to be within such district as may be prescribed by the **L.G.B.**, and in the absence of such prescription, then within the nearest district (s. 110).

Right of entry upon private premises.—The **S.A.** and their officers have rights of entry between 9 a.m. and 6 p.m., and in the case of a nuisance arising in respect of any business, at any hour when such business is in progress. If admission be refused a Justice's order may be obtained (sections 102 and 103).

Offensive trades. It is illegal to establish an offensive trade within the district of an urban **S.A.** without their consent. The offensive trades are: blood boiler, bone-boiler, fellmonger, soap-boiler, tallow-melter, tripe-boiler, any other noxious or offensive trade, business, or manufacture (s. 112). An urban

* This section originally brought ships under those provisions of the Act that relate to nuisances only; but the Public Health (Ships) Act, 1885, extended its scope to include also infectious diseases and [illegible] (sections 120, 121, 124, 125, 126, 128, 131, 132, and 133).

S.A. may make byelaws with respect to such trades as have been established with their consent,* to prevent or diminish nuisance arising therefrom (s. 113). If the **M.O.H.**, or two medical practitioners, or ten inhabitants, certify that any of the premises named below are a nuisance, or injurious to health, the **S.A.** must take proceedings against the offender, who is liable to penalty, unless he can show that he has used the best practical means for abating such nuisance, or preventing or counteracting such effluvia. The premises in question are : candle-house, melting-house, melting-place, soap-house, slaughter-house, any building or place for boiling offal or blood, or for boiling, burning, or crushing bones, or any manufactory, building, or place used for any trade, business, process, or manufacture, causing effluvia (s. 114). The same powers are applicable in the case of nuisances affecting the inhabitants of a district, but resulting from premises situated beyond the limits of the district.

[As regards the prohibition (s. 112) of the establishment of any given trade without the consent of the **S.A.**, it is incumbent upon the prosecuting authority to show that the trade is either one of those specifically mentioned above, or *ejusdem generis* with them; that is, that it is necessarily an offensive trade apart from neglect or mismanagement. The higher Courts have held that this is the case with rag and bone stores for example, but not with brick-making, manure works, or fish-frying. Nevertheless, a very large number of trade processes to which the above restriction may be considered inapplicable will come within the scope of s. 114, if it can be shown that they are carried on so as to give rise to effluvium nuisances.]

* As this consent only became necessary in 1848, the byelaws can only *apply to* trades established since that date.

Unsound food.—The **M.O.H.** or Inspector of Nuisances may, at all reasonable times, examine any animal,* carcase, meat, poultry, game, flesh, fish, fruit, vegetables, corn, bread, flour, or milk, exposed for sale, or deposited for the purpose of sale, or of preparation for sale, and intended for the food of man; and may seize the same if diseased, unsound, or unwholesome, and take it to a magistrate, who may order it to be destroyed, and inflict a penalty upon the offender. The proof that it was not intended for the food of man rests with the person charged (sections 116, 117). Any person obstructing is subject to penalty (s. 118). On complaint made on oath a Justice may grant a search warrant to the **M.O.H.** or Inspector.

[Eggs, butter, cheese, and other important articles of food, are not mentioned specifically, and are, therefore, not included in the scope of the Act. No proceedings can be taken in regard to articles already sold. Both these defects are avoided in the Public Health Amendment Act of 1890, and in the Public Health (London) Act, 1891.]

Infectious diseases.—Upon the certificate of the **M.O.H.** or other medical practitioner that the cleansing and disinfecting of any house or part thereof, and of any articles therein, would tend to prevent infectious diseases, it is incumbent on the **S.A.** to serve notice upon either the owner or occupier, requiring him to cleanse and disinfect. A penalty is incurred by default, and the **S.A.** may do what is necessary and recover the costs, or may undertake this duty in the first instance, with the consent of the occupier, at their own cost (s. 120). The **S.A.** may destroy infected bedding, clothing, or other articles, and give compensation (s. 121); may provide a disinfecting apparatus and disinfect free of charge

* *Living* animals can be seized under this section

(s. 122); may provide an ambulance and pay expenses of conveyance of infectious persons to hospital (s. 123).

Where a hospital is provided within convenient distance, a Justice may, on the certificate of a medical practitioner, order the removal of any person who is suffering from any dangerous infectious disorder, and is without proper lodging or accommodation, or lodged in a room occupied by more than one family,* or is on board any ship or vessel (s. 124). The **S.A.** may make regulations for removing to any available hospital, and for keeping there as long as necessary, any persons brought within their district by vessel who are infected with a dangerous infectious disorder (s. 125).

It is unlawful for any person so suffering to expose himself wilfully, without proper precautions against spreading the disorder, in any street, public place, shop, inn, or public conveyance, or to enter any public conveyance without previously notifying to the owner, conductor, or driver thereof that he is so suffering; or, being in charge of any person so suffering, to expose such sufferer, or to give, lend, sell, transmit, or expose without previous disinfection any bedding, clothing, rags, or other things which have been exposed to infection from any such disorder; but this does not apply to the transmission with proper precautions of articles for the purpose of having them disinfected (s. 126). The owner or driver of a public conveyance so used is required under penalty to have the same immediately disinfected, but he need not convey any person so suffering until he has been paid a sum sufficient to cover any loss or expense incurred by him (s. 127). Any person who knowingly lets for hire any house, or room, in

* *This detail is omitted as superfluous in the London Act of 1891; but lodgment in a tent or van is made per se a reason for removal.*

which any person has suffered from such disorder, without having it and the contents disinfected to the satisfaction of a medical practitioner as testified by a certificate signed by him, is liable to penalty (s. 128). Any person letting or offering for hire any house, or part of a house, who on being questioned as to the fact of there being, or within six weeks previously having been therein, any person suffering from any dangerous infectious disorder, knowingly makes a false answer to such question, becomes liable to penalty or imprisonment (s. 129).

Special Regulations of L.G.B. The **L.G.B.** may make regulations for the treatment of persons affected with cholera, or any other epidemic, endemic, or infectious diseases, and for preventing the spread of such diseases as well on the seas, rivers, and waters of the United Kingdom, and on the high seas within three miles of the coast thereof, as on land, and may declare by what Sanitary Authorities such regulations shall be enforced and executed (s. 130). Cholera Regulations have been issued under this section (p. 463).

Furthermore, whenever any part of England appears to be threatened with, or is affected by, any formidable epidemic, endemic, or infectious disease, the **L.G.B.** may make, and from time to time alter or revoke, regulations for any of the following purposes, viz. for the speedy interment of the dead, for house-to-house visitation, for the provision of medical aid and accommodation, for the promotion of cleansing, ventilation, and disinfection, and for guarding against the spread of disease; and may by order declare all or any of the regulations so made to be in force within the whole or any part of the district of any **S.A.**, and to apply to any vessels whether on inland waters or on parts of the sea within the jurisdiction of the Lord High Admiral of the *United Kingdom* (s. 134). The **S.A.'s** are required

to do everything that is necessary to carry out these regulations.

Hospitals.—Any **S.A.** may build or contract for the use of hospitals for their district. Two or more **S.A.'s** may combine for this purpose (s. 131). The **S.A.** may recover from a patient, who is not a pauper, the cost of his maintenance (s. 132). The **S.A.** may with the sanction of the **L.G.B.** themselves provide or contract for a temporary supply of medicine and medical assistance for the poor of their district (s. 133). (*See also* Isolation Hospitals Acts.)

Mortuaries.—Every **S.A.** *may*, and, if required by the **L.G.B.**, *must*, provide a mortuary, and may make byelaws with respect to its management and charges for its use. They may also provide for the decent and economical interment, at charges to be fixed by such byelaws, of any dead body which may be received into a mortuary (s. 141). A Justice may, on a certificate signed by a practitioner, order to be removed to a mortuary, at the cost of the **S.A.**, (1) the body of anyone who has died of any infectious disease, and which is retained in a room in which persons live or sleep, or (2) any dead body which is in such a state as to endanger the health of the inmates of the house or room in which it is retained. He may direct the same to be buried within a specified time. If the friends fail to comply, it is the duty of the Relieving Officer to bury, and the expenses may be recovered from the proper person (s. 142). The **S.A.** may provide a place for the post-mortem examination ordered by a coroner.

New streets and buildings.—In urban districts all public streets (*i.e.* those reparable by the inhabitants at large) are vested in the **S.A.**, who *shall* cause them *to be* levelled, paved, and repaired, as occasion may require (s. 149). The owners of property abutting on any private street or part of a street may

be required by the (urban) **S.A.** to level, pave, sewer, light, or make good such street or part of a street; and in case of default the **S.A.** may carry out the work and recover the expenses from the owners according to the frontage of their respective premises (s. 150). An urban **S.A.** may make byelaws with regard to new streets and buildings. For the purposes of the Act the re-erection of any building pulled down to or below the ground floor, or the conversion into a dwelling-house of any building not originally constructed for human habitation, or the conversion into more than one dwelling house of a building originally constructed as one dwelling-house only, shall be considered the erection of a new building (s. 159).

*Dangerous structures.**—The surveyor of an urban **S.A.**, if satisfied that any building or wall is in a ruinous state so as to be dangerous to passengers or to the inmates of neighbouring houses, shall cause a fence to be put up, and shall order the owner forthwith to secure or pull down such building, and in default thereof the surveyor may obtain a Justice's order to carry out the necessary works, and may recover the expenses. (Towns Improvement Clauses Act, sections 75-78, incorporated with the Public Health Act by s. 160 of the latter.)

Rain-pipes and eaves-gutters.—An urban **S.A.** may compel the owner of any building adjoining or near to a street to provide within seven days efficient eaves-gutters and rain pipes. (Towns Improvement Clauses Act, s. 74; Public Health Act, s. 160.)

Slaughter-houses.—An urban **S.A.** may provide abattoirs or slaughter-houses, and if they do so may make byelaws with respect to management

* These and some of the following provisions are not in the [illegible] text of the Public Health Act, but in the incorporated [illegible] Towns Improvement Clauses Act.

charges (s. 169). They may also license slaughter-houses and knackers' yards, and without their licence no place shall be used for such purposes which was not so used at the time of the passing of the Act, *i.e.* in 1875. Every place used as a slaughter-house or knackers' yard shall be registered by the owner or occupier in a book kept by the **S.A.** An urban **S.A.** *must* make byelaws in regard to slaughter-houses and knackers' yards. If any person is convicted of killing or dressing any cattle contrary to the provisions of the Public Health Act, or of the non-observance of any of the byelaws or regulations made under this Act, the Justices before whom he is convicted may suspend the licence for two months or less, and in the event of a second offence may revoke the licence. (Sections 125 to 130 Towns Improvement Clauses Act, incorporated in the Public Health Act by virtue of s. 169.)

A legible notice bearing the words Licensed Slaughter-House or Registered Slaughter-House must be attached and maintained in some conspicuous place on every registered slaughter-house by the owner or occupier (s. 170).

Combination of sanitary authorities for appointment of Medical Officer of Health. The **L.G.B.** may (compulsorily or otherwise) unite two or more districts situated wholly or partially in the same county, for the purpose of appointing a Medical Officer of Health; but no urban district with more than 25,000 inhabitants shall be included without the consent of the **S.A.**, and in the event of any **S.A.** objecting to being included, the **L.G.B.** can only include their district by means of Provisional Order subject to confirmation by Parliament (s. 286).

A **S.A.** may delegate all or any of its powers to a committee of its own members (sections 200 and 201); and a rural authority may form parochial committees

consisting wholly or partially of its own members, and may give to such committees certain limited sanitary functions (s. 202). (*See* under Loc. Govt. Act, p. 510.)

Urban powers for rural districts.—The **L.G.B.** may give to a rural **S.A.**, as regards the whole or part of their area, any powers and responsibilities conferred by this Act upon urban **S.A.'s** (s. 276).

Special drainage districts.—A rural **S.A.** may, with the consent of the **L.G.B.**, constitute any portion of their area a *special drainage district* for the purpose of charging thereon exclusively the expenses of works of sewerage, water supply, or other works which may be declared by the **L.G.B.** to be *special expenses*, and thereupon such area shall become a *separate contributory place* (s. 277). The **S.A.** have also power to declare expenses which they have incurred to be *private improvement expenses*, and to charge a special *private improvement rate* in respect thereof upon the estate benefited (sections 213 and 232).

Union of districts for sanitary purposes.—Joint boards may be formed, by order of the **L.G.B.**, for the purpose of water-supply or sewerage, or for other purposes of the Public Health Act, as applied to a district comprising the whole or parts of two or more sanitary districts (s. 279). Under this section joint Hospital Boards may be formed.

Default of **S.A.** If satisfied, after due inquiry, that any **S.A.** have made default in providing or maintaining sewers, or in providing and maintaining a supply of pure water,* or in enforcing any provisions of the Public Health Act which it is their duty to enforce, the **L.G.B.** shall make an order limiting a time for the performance of their duty in the matter. If such duty is not performed in the time allowed,

* "In cases where danger arises to the health of the inhabitants from the insufficiency or unwholesomeness of the existing supply of water, and a *proper supply* can be got at a reasonable cost."

the order may either be enforced by writ of *mandamus*, or the **L.G.B.** may appoint some person to perform the work, and charge all expenses to the authority in default (s. 299).

[The 7th section of the Housing of the Working Classes Act, 1885, has a wider scope.]

Port Sanitary Authority.—The **L.G.B.** may, by order, constitute any **S.A.** whose district abuts upon any port in England the **S.A.** for the whole or for any part of such port. The Board may also combine two or more riparian authorities for the purpose; or may constitute one Port **S.A.** for any two or more ports. The Authority may be constituted permanently or temporarily. The order constituting the Authority may assign to it any of the powers or duties of an urban **S.A.** so far as applicable to a Port **S.A.**, and to vessels, waters, or persons within its jurisdiction—namely, under sections 91 to 111 (nuisances), 120 to 133 (infectious diseases and hospitals), 134 to 138 (prevention of epidemic diseases), 141 and 142 (mortuaries), 182 to 186 and 188 (byelaws), 189 (appointment of **M.O.H.** and inspector of nuisances), and other sections.*

The **Public Health (Water) Act, 1878,** applies to every rural **S.A.**, and also to such urban **S.A.'s** as the **L.G.B.** may order (sections 3 and 11). Every rural **S.A.** shall see that every occupied dwelling-house within their district has, within reasonable distance, an available and sufficient supply of wholesome water. If the **M.O.H.** reports that an occupied house is without such supply, and the **S.A.** are of opinion that such a supply can be provided at a

* The powers and duties of a Port **S.A.** and its officers consist primarily of those conferred by such of the specified portions of the Public Health Act as the particular Order may decide. They are extended by the Cholera Regulations (page 469), and the Order prescribing the duties of the Port **M.O.H.** A ship comes within the definition of "house" for many purposes (page 489)

reasonable cost (the interest on which, at 5 per cent., shall not exceed twopence or threepence per week, as the **L.G.B.** may, on the application of the **S.A.**, determine to be reasonable in the circumstances), the **S.A.** may require the owner (subject to appeal to the **L.G.B.**) to provide such supply within a specified time, and, in case of default, may themselves carry out the necessary works at his expense. It remains, however, the duty of the **S.A.** to provide any part of their district with a supply of water, in cases where danger arises to the health of the inhabitants from the insufficiency or unwholesomeness of the existing supply, and a general scheme of supply is required, and can be got at reasonable cost (s. 3).

The owner of any dwelling house in a rural district that may be erected or rebuilt from the ground floor after the date of this Act shall not permit such house to be occupied without a certificate from the **S.A.** that it is provided with a sufficient and available supply of wholesome water, such certificate to be based on the report of the **M.O.H.** or inspector (s. 6). If the **S.A.** provide a stand-pipe for water-supply, they may levy water charges upon every dwelling within 200 feet, as if the supply were given on the premises; not, however, upon such houses as have a good supply within reasonable distance, from another source, unless water from the stand-pipe is used by the inmates (s. 9).

Every rural **S.A.** must, through their officers or otherwise, provide for the periodical inspection of the water-supply of their district. The same powers of entry upon premises are given as are conferred by sections 102 and 103 of the Public Health Act, 1875, in respect of nuisances (s. 7).

The Public Health Act, 1896, repeals the old Quarantine Act of 1825, and extends the powers of the **L.G.B.** to make Orders under sections 130 and

134 of the 1875 Act, dealing with epidemic, endemic, or infectious diseases. Accordingly, regulations as to cholera, yellow fever, and plague were issued in an Order dated November 9th, 1896.

The Public Health (Ports) Act, 1896, enables the **L.G.B.** to issue orders making all or any of the provisions of the Infectious Diseases Prevention Act, 1890, applicable to any Port Sanitary Authority.

The Public Health Acts Amendment Act, 1890, is an "adoptive" Act, of which Part III. is concerned with sanitary matters. Urban **S.A.'s** may by resolution adopt any part of the Act; rural Authorities can adopt those powers which are not expressly limited to urban districts, and as regards the rest, can apply to the **L.G.B.** for full urban powers in the same manner as under the 1875 Act.

The following are the chief provisions of Part III.

Sewers.—It is unlawful to pass into any drain or sewer (*a*) any substance which may injure it or impede the flow of its contents; or (*b*) any chemical refuse, or waste steam, or water or other liquid heated above 110° F., which either alone or in combination with sewage causes a nuisance or is dangerous to health.

Closets, etc.—Where any sanitary convenience is used in common by the occupants of two or more houses, any person fouling or injuring it is liable to penalty; and if nuisance arises from want of cleanliness of any part of it or of the approaches, each of the persons having the right of use is liable to penalty, in the absence of proof as to which of them is in default. Sufficient and suitable sanitary conveniences must be provided in all factories and workshops; with separate accommodation for each sex, where persons of both sexes are employed (s. 22).

Byelaws.—Urban **S.A.'s** may make byelaws respecting public sanitary conveniences provided by

them. Section 157 of the 1875 Act is extended so as to enable any urban **S.A.** to make further byelaws concerning new buildings, upon the following points: (*a*) adequate water supply to closets; (*b*) construction of floors, hearths and staircases; (*c*) height of rooms intended for habitation; (*d*) paving of yards and open spaces in connection with houses; (*e*) provision of secondary approaches to houses, for the purpose of removing refuse. It is further provided that byelaws respecting closets and drainage may be made applicable to old as well as new houses. Similar power of framing byelaws respecting buildings (under s 157 as amended) is given to rural **S.A.'s**, but with certain exceptions. [Apart from this the **L.G.B.** can, as already stated, grant full urban powers to rural Authorities.] Any **S.A.** may make byelaws to prevent buildings erected in accordance with byelaws from being altered in such a way that if at first so constructed they would have contravened the byelaws.

An urban **S.A.** may make byelaws respecting the carriage through the streets of offensive matter or liquid, prescribing (*a*) certain hours for such removal, (*b*) proper construction and covering of the receptacle used for the removal, and (*c*) the cleansing of any place fouled by matters dropped or spilled.

Any **S.A.**, themselves undertaking or contracting for the removal of house-refuse, may make byelaws imposing upon the occupier duties in connection with such removal.

Polluted sites.—No new building may be erected upon ground impregnated with animal or vegetable matter, or upon which such matter has been deposited, unless such matter has been properly removed or has become innocuous. If (in an urban district) any portion of a room is immediately over any privy (not being a water closet or earth-closet), cesspool, midden, or ash-pit, it is illegal to occupy it, or suffer it to be

occupied, as a dwelling-place, sleeping-place, work-room, or place of business.

Cleansing of common passages.—If in an urban district any private court or passage, leading to the back of several buildings separately occupied, is not regularly and effectually swept and kept clean, the **S.A.** may cause it to be swept and cleaned, and recover the expenses from the occupiers.

Pollution of streams by solid refuse.—It is forbidden "to throw or place . . . . in any . . . . water-course within any district in which this part of this Act is adopted, any cinders, ashes, bricks, stone, rubbish, dust, filth, or other matter which is likely to cause annoyance."

Food.—Sections 116—119 of the 1875 Act are extended so as to apply to "all articles intended for the food of man, sold or exposed for sale, or deposited in any place for the purpose of sale, or of preparation for sale." A Justice may condemn any such article and order it to be destroyed, if satisfied that it is diseased, unsound, unwholesome, or unfit for the food of man, even if it has not been formally seized under s. 116.

Slaughter-houses.—Licences granted after the adoption of this Act are to remain in force only for such period, not being less than a year, as the **S.A.** shall specify in the licence. Every change of occupation of a licensed slaughter-house must (under penalty) be notified in writing to the inspector of nuisances; and notice of this requirement must be endorsed on all new licences. If the occupier of any licensed slaughter-house is convicted under sections 116—119 of the 1875 Act, the Court may revoke the licence.

Common lodging-houses.—A penalty is imposed upon the keeper if he fails to give notice of any case of infectious disease, as required by s. 84 of the 1875 Act (page 486).

The Act does not apply to London.

The Infectious Diseases Prevention Act, 1890, is another adoptive or optional Act; and any extra-metropolitan **S.A.** may by resolution adopt all or any of its sections, and may by further resolution rescind them. For London its leading provisions are contained in the Public Health (London) Act. The infectious diseases to which this Act applies are those specified in (or added to) the Infectious Diseases Notification Act. The principal provisions are as follows:—

Milk supplies.—If the **M.O.H.** has reason to believe that the consumption of milk from any dairy* (within or without his district) has caused or is likely to cause infectious disease to any person residing in the district, he may (if authorised by a Justice having jurisdiction in the place where the dairy is situate) inspect the dairy. He may further, if accompanied by a veterinary surgeon, inspect the animals therein. If after inspection he is of opinion that infectious disease is caused by consumption of the milk, he must report to the **S.A.,** forwarding also any report furnished to him by the veterinary surgeon. The **S.A.** may then give not less than 24 hours' notice to the dairyman to appear before them, and show cause why the supply of the milk in their district should not be prohibited. If in their opinion he fails to show such cause, they may order accordingly, and must give notice of the facts to the **S.A.** and the County Council of the district in which the dairy is situate, and to the **L.G.B.** The order must be forthwith withdrawn on the **S.A.** or the **M.O.H.** being satisfied that the milk supply has been changed, or that the cause of infection has been removed. Penalties are provided for contravention of this section of the Act.

Disinfection.—Where the **M.O.H.** or any regis-

* Including any farm, farmhouse, cowshed, milk store, milk shop, or other place from which milk is supplied or in which it is kept for the purpose of sale.

tered medical practitioner certifies that the cleansing and disinfection of any house, or part thereof, and of any articles therein, would tend to prevent infection, the **S.A.** may, after 24 hours' notice to the owner or occupier, proceed to carry out such disinfection or cleansing, unless within that time he informs the **S.A.** that he will, within a period fixed in the notice, himself carry out the work to the satisfaction of the **M.O.H.** If he fail to do this within the specified period, it is to be done by the officers of the **S.A.**, under the superintendence of the **M.O.H.**, and the expenses may be recovered. Power of entry between 10 a.m. and 6 p.m. is given for the purposes of this section. Where the section is adopted, the 120th section of the Public Health Act, 1875, is repealed.

The **S.A.** may, by written notice, require (under penalty) any infected clothing or other articles to be delivered to their officer for disinfection. The **S.A.** must take away, disinfect, and return such articles free of charge, and, in the event of any unnecessary damage, must compensate the owner.

Any person who shall cease to occupy any house or room in which any person has, within six weeks, been suffering from any infectious disease (*a*) must have such house or room (and all articles therein liable to retain infection) disinfected to the satisfaction of a registered medical practitioner, as testified by a certificate signed by him; (*b*) must give to the owner notice of the previous existence of such disease; and (*c*) must not knowingly make a false answer when questioned by the owner, or by any person negotiating for the hire of the house or room, as to there having, within six weeks previously, been therein any person suffering from any infectious disease. Penalties are provided in each case. The **S.A.** must give notice of the provisions of this section to the occupier of any house in which they

are aware there is a person suffering from an infectious disease.

Prompt interment.—The body of a person who has died of any infectious disease must not, without a certificate from the **M.O.H.** or a registered medical practitioner, be retained for more than 48 hours elsewhere than in a mortuary, or in a room not used at the time as a dwelling-place, sleeping place, or workroom. In such cases, and also where any corpse is retained in a building so as to endanger the health of the inmates, a Justice may, upon the application of the **M.O.H.**, order the body to be removed by the **S.A.** to a mortuary, and to be buried within a specified time. Unless the friends undertake to bury, and do bury within the specified time, the relieving-officer must do so The body of any person who has died from infectious disease in a hospital must not be removed except for immediate interment or to a mortuary, if the **M.O.H.** or a registered practitioner certify that such restriction is desirable for preventing infection. The body of any person who has died from an infectious disease must not be conveyed in any public conveyance (other than a hearse) without due warning to the owner or driver, who must forthwith provide for disinfection.

Detention in hospital.—Any person suffering from any infectious disease, and being an inmate of a hospital for infectious diseases, and who upon leaving would be without accommodation in which due precautions could be taken against the spread of infection, may, by order of a Justice, be detained in hospital (at the cost of the **S.A.**) for any specified period, and such period may be extended as often as necessary.

The **S.A.** shall provide free temporary shelter, with any necessary attendance, for the members of any family in which infectious disease has appeared, who have to leave their dwellings to allow of disinfection by the **S.A.**

Infectious rubbish must not be thrown into any receptacle for refuse without previous disinfection. Notice of this prohibition must be served by the **S.A.** upon the master of any house in which there is any case of dangerous infectious disease.

The Isolation Hospitals Act, 1893, gives to County Councils limited power to secure the provision of isolation hospitals in their various counties. It applies to England and Wales generally, but not to London or to any county borough; other boroughs also are exempt, except by Order of the **L.G.B.,** if the population be less than 10,000 (according to the latest census), or by consent of the corporation if the population be 10,000 or more.

A *Hospital District* may consist of one or more local areas; a "local area" includes an urban or rural sanitary district, or any "contributory place," and is constituted by Order of the County Council.

Procedure.—The County Council may take the initiative by directing their **M.O.H.** to report as to the hospital requirement of any part of their county, and acting upon his report; but they may also be set in motion by a petition from any local authority or from twenty-five ratepayers in any contributory place. The next step is for the County Council to hold a local inquiry, after which they make an Order constituting the hospital district and defining its extent. No local area can be included in a hospital district without the consent of its local authority, if it already has (in the judgment of the County Council) adequate accommodation; nor must a hospital district be formed for one local area only, or for one or more local areas within the same rural sanitary district, without the consent of the **S.A.,** unless the County Council are satisfied that the **S.A.** are unable or unwilling to make suitable provision for the purpose. The Order constitutes a hospital

committee, consisting of local representatives, but if a grant be made out of county funds the committee may consist wholly or in part of county councillors. The Order further gives the committee power to provide and maintain a hospital; and apart from this they are authorised by the Act to make temporary arrangements for isolation, and to establish district hospitals in cottages or small buildings. They may also (subject to any regulations made by the County Council) undertake the training of nurses, and may charge for their attendance outside the hospital. Every hospital is to be provided with one or more ambulances, and must, if practicable, be "in connection with the system of telegraphs."

The County Council have the power of inspecting any such hospital, and of raising money by loan for the purposes of the hospital.

Expenses.—"Structural" (*e.g.* site, building, furnishing, extensions, etc.) and "Establishment" (*e.g.* maintenance of hospital, salaries, etc.) expenses are borne by the several local rates of the constituent local areas, in proportions to be fixed by the Order. The costs of conveying, removing, feeding, medicines, disinfecting, and "all other things required for patients individually, exclusive of structural and establishment expenses," are termed *patients' expenses.* For ordinary non pauper patients they are to be paid by the local authority out of the rates of the local area from which the patient came, but the Guardians are responsible if Poor Law relief had been given at or within a fortnight of the time of admission. Patients desiring exceptional accommodation are themselves responsible for the cost of maintenance, etc., on such terms ("special patients' expenses") as the committee may appoint.

The Isolation Hospital Act, 1901, provides that a **S.A.** having possession of a hospital for the

reception of the sick may, with the sanction of the **L.G.B.**, transfer it to the County Council for appropriation to a district under the Isolation Hospitals Act, 1893, as an infectious diseases hospital, and the County Council may contribute to the expenses of such a hospital. Minor amendments and definitions are included in the Act.

Midwives Act, 1902, is another Act directly concerned with disease-prevention, and may therefore be quoted here. The duties of the Local Supervising Authorities (the Councils of Counties or County Boroughs, or bodies to whom they may delegate their powers) are defined in Rules drawn up by the Central Midwives Board under s. 3, and approved by the Privy Council on 12th August, 1903. In addition to the registration of midwives, the following duties arise under s. 3 :—

(1) To exercise a general supervision over all midwives practising within their area, in accordance with the above rules.

(2) To investigate charges of malpractices, negligence, or misconduct on the part of a midwife. If a *primâ facie* case be established, it is to be reported to the Central Board.

(3) To suspend a midwife from practice, when necessary, in accordance with the Midwives Board rules.

The rules in question include the following :—

Whenever a midwife has been in attendance upon a patient suffering from puerperal fever, or from any other illness supposed to be infectious, she must disinfect herself, and all her instruments and other appliances, to the satisfaction of the **S.A.**, and must have her clothing thoroughly disinfected before going to another labour. Unless otherwise directed by the Local Supervising Authority, all washable clothing should be boiled, and other clothing should be stoved (by the **S.A.**) and then exposed to the open air for several days.

Formal notification must be made by the midwife to the Local Supervising Authority when any of the following occur :—

(*a*) When the mother or the child dies without having been seen by a registered medical practitioner:

(*b*) When the child is deemed to be stillborn

(*c*) When, owing to the occurrence of various complications either of the labour or of its after-course, as defined in the rules, it has been necessary for the midwife to advise that a registered medical practitioner be sent for."

The Local Supervising Authority must secure proper inspection of every midwife's case book, bag of instruments and appliances, etc., and must, when necessary, make arrangements for inspection of her residence, and for investigation of her mode of practice.

The Local Supervising Authority are to suspend from practice a midwife who contravenes the directions issued for the use of disinfectants and for the proper safeguards against the spread of infection laid down by the Central Board, or other rules of the Board. Any suspension (with the grounds thereof) must be reported to the Central Board.

Local Government Act, 1888.—The sanitary provisions of this important Act are few. Besides the powers in respect of pollution of streams conferred upon County Councils by s. 14, and the provisions as to the appointment and qualifications of county and other **M.O.H.** contained in sections 17 and 18 (page 465), only the following require mention here:

> A County Council may, subject to the approval of the **L.G.B.**, make byelaws in relation to the whole or any specified part of their county (boroughs excepted*) for various purposes, including the prevention and suppression of nuisances not already punishable in a summary manner by virtue of any Act in force throughout the county (s. 16).
>
> Every **M.O.H.** for a district in any county shall send to the County Council a copy of every periodical report † of which a copy is, for the time being, required by the regulations of the **L.G.B.** to be sent to the Board; and if the **M.O.H.** fail to send such copy, the County Council may refuse to pay any contribution towards his salary. If it appear to the County Council from any such report that the Public Health Act, 1875,

* Boroughs have the same power under s. 23 of the Municipal Corporations Act, 1882.

† The Regulations of the **L.G.B.** require the **M.O.H.** to furnish the County Council with copies of special as well as annual reports. (*See page 469.*)

has not been properly put in force within the district to which the report relates, or that any other matter affecting the public health of the district requires to be remedied, the Council may cause a representation to be made to the **L.G.B.** on the matter (s. 19).

County Councils have now certain powers under the Housing of the Working Classes Act, and they have, of course, power to make formal or informal representations to the **L.G.B.**, or other controlling authority, upon any matter.

The Local Government Act, 1894, does not apply to county boroughs, or to London, Scotland, or Ireland.

Area and Boundaries.—Boundaries are to be adjusted so as to prevent intersection of those which define counties, county districts, unions, and parishes. Small rural parishes are to be grouped into workable units for parish council purposes, but each is to have its parish meeting. In rural districts *Parish Meetings* and *Parish Councils* are constituted.

The Parish Meeting has the exclusive power of adopting certain optional Acts, including the Burials Acts and the Baths and Washhouses Act, and its consent is required before the Parish Council can incur any expense involving a loan or a rate exceeding 3d. in any year.

The Parish Council have power (s. 8) "to utilise any well, spring, or stream within their parish and provide facilities for obtaining water therefrom,* but so as not to interfere with the rights of any corporation or person; and to deal with any pond, pool, open ditch, drain, or place containing or used for the collection of any drainage, filth, stagnant water or matter likely to be prejudicial to health, by draining, cleansing, covering it, or otherwise preventing it from being prejudicial to health, but so as not to interfere with any private right or the sewage or

* They cannot, except by agreement, acquire land for the purpose of any supply of water (s. 9).

drainage works of any Local Authority." They may execute works for these purposes, or contribute to the cost. They may complain (s 16) to the County Council if the Rural District Council have failed to provide or to maintain sufficient drainage or water supply for the parish, or to enforce any provision of the Public Health Act, and in that event the County Council may take over to themselves the powers of the District Council for the purpose, or may make an Order for the necessary works to be carried out by the District Council or by some person appointed by the County Council. Notice must be given to the Parish Council concerned if the Rural District Council decide to undertake works of sewerage or water supply. The Parish Council may acquire or hire land for allotments, and may, if necessary, appeal to the County Council for compulsory powers of purchase or hire; the Order if granted requires confirmation by the **L.G.B.** (sections 9 and 10). They may also make official representations to the District Council under the Allotments Acts; or to the **M.O.H.** as to unhealthy dwellings or obstructive buildings under the Housing of the Working Classes Act (*see* p. 512 *et seq*), or to the **L.G.B.** with a view to the grant of urban powers for their parish or any part of it. The District Council may delegate to them any powers which under the Public Health Acts could be delegated to a parochial committee (page 496). Apart from expenditure under adoptive Acts, the Parish Council must not incur expenses involving more than a 6d rate in any year, nor more than a 3d. rate without the consent of the parish meeting. They may raise money on loan, but only with the approval of the parish meeting, the County Council, and the **L.G.B.**

Rural District Councils, notwithstanding the limited *initiative* possessed by the Parish Council

to confirmation by Parliament. It may modify the scheme, and must determine the extent of the provision to be made for the working classes displaced. In London, accommodation must be provided in or near the area for the whole number displaced, unless the Order decrees otherwise; under certain conditions the Order may accept in substitution equally convenient accommodation not in or near the area, and may dispense with the obligation to any extent not exceeding one half. Outside the metropolis such provision is only compulsory if (and to the extent) prescribed by the Order. In assessing the value of property, no additional allowance for compulsory purchase is to be made in regard to any unhealthy portion of the area; and evidence may be given showing that any premises are (1) unfit for habitation, and cannot reasonably be made fit; or (2) in bad repair, or in an insanitary condition; or (3) that the rental is enhanced by reason of overcrowding or use for illegal purposes. In the first case the compensation is to be based upon the value of the land and building materials only; in the second, upon the value after allowing for the cost of necessary repairs; in the third, upon the value apart from such illegal use. After the provisional Order has been confirmed by Parliament, it becomes "the Confirming Act," and is executed by the local authority who take steps to receive and adjudicate upon claims, if necessary submitting them to arbitration.

Upon complaint by two Justices, or twelve ratepayers, the **M.O.H.** must inspect and report upon any area. If he fails to do so, or reports that it is not an unhealthy area, such ratepayers may appeal to the Confirming Authority, who may then appoint a medical practitioner to inspect the area. If the latter reports that it is an unhealthy area, the **S.A.** are required to prepare an improvement scheme. In any

case, if the **S.A.** refuse or fail to prepare a scheme upon receipt of an official representation, they must report the facts to the Confirming Authority, who may then order a local inquiry to be held.

Part II. applies to rural as well as urban districts, and relates to *unhealthy or obstructive dwellings.* It is the duty of the **M.O.H.** to represent to the **S.A.** any dwelling which appears to him to be in a state dangerous to health so as to be unfit for human habitation; but the **S.A.** are also required to cause inspections of their district to be made from time to time for the same purpose. If satisfied that any dwelling is unfit for habitation, the **S.A.** must first take proceedings against the owner for the closure of the house, as directed by the Public Health Act, 1875 (*See* pp. 488-9.) If the closing order of the court is not terminated by a further order, the **S.A.** may proceed to make an order for the demolition of the premises; but before doing so must afford the owner an opportunity of stating his objections. There is an appeal to Quarter Sessions. Upon written complaint from four or more householders that any dwelling is unfit for habitation, the **M.O.H.** must inspect such house, and report to the **S.A.** If the **S.A.** (not being a rural **S.A.**, or in the county of London) fail to take action within three months, the complainants may appeal to the **L.G.B.**, who may, after local inquiry, order the **S.A.** to proceed.

Obstructive Buildings.—If the **M.O.H.** finds that any building—though not in itself unfit for habitation —by its proximity to other buildings, either (*a*) stops ventilation, or otherwise conduces to make them unfit for habitation, or (*b*) prevents the proper remedy of any nuisance or other evils in respect of such other buildings, he must make a representation to the **S.A.**, stating that in his opinion the obstructive building should be pulled down. A similar repre-

sentation may be made by any four or more inhabitant householders. In either case the **S.A.** must make inquiry as to the facts, and as to the cost of acquiring the land and pulling down the building. If they decide to proceed, the **S.A.** can make an order for the demolition of the building, after giving the owner an opportunity of stating his objections, and subject to appeal to Quarter Sessions. The compensation to be paid by the **S.A.** to the owner, and also the amount recoverable by the **S.A.** from the owners of the houses benefited by the demolition, are settled by arbitration in case of dispute.

The **S.A.** may prepare a scheme for dedicating as a highway or open space, or appropriating or exchanging for the erection of working-class dwellings, the site of any building ordered to be demolished under Part II., if it appears to them that it would benefit the health of the inhabitants of the adjoining houses. They may also prepare an improvement scheme for any unhealthy area too small to be dealt with under Part I. Such schemes require confirmation by provisional Order of the **L.G.B.** after a local inquiry, and with or without modification. The Order may require provision to be made for the accommodation of persons of the working-classes displaced. When an official representation has been made under Part II., or a closing order obtained, a rural **S.A.** must forward a copy to the County Council, and report from time to time all further proceedings. If it appears to the County Council that a closing order should be applied for, or an order for demolition made, and if the **S.A.**, after due notice from the County Council, fails to adopt such measures, the Council may by resolution take over and exercise the powers of the **S.A.** in respect of such buildings, recovering the expenses from the **S.A.** Except in boroughs, a representation by the county **M.O.H.**

if forwarded by the County Council to any **S.A.**, has, for the purposes of Part II., the same effect as if made by the **M.O.H.** of the district.

In the county of London, Part I. is entrusted to the County Council, and Part II. primarily to the Borough Councils. In the event of doubt, the Home Secretary has to decide under which part of the Act a given area shall be dealt with. But the County Council may prepare schemes under Part II. if they think fit, and may apply to the Home Secretary to order a contribution from the District Authority, who, in like manner, if they proceed, may apply for a contribution from the County Council.

Part III. authorises the **S.A.** to provide lodging-houses for the working classes, subject to the sanction of the **L.G.B.** as regards urban authorities, and of the County Council in rural districts; and to make bye-laws respecting such houses. For the administration of this part of the Act it is necessary for the **S.A.** to adopt it.

The administration of Parts I., II., and III. in the district of the City of London is vested in the Commissioners, and the County Council have no jurisdiction in this area.

Part IV. contains supplemental provisions, of which the following is important:—"In any contract made after August 14th, 1885, for letting for habitation by persons of the working classes a house or part of a house, there shall be implied a condition that the house is at the commencement of the holding in all respects reasonably fit for human habitation."

Housing of the Working Classes Act, 1900.—This Act amends Part III. of the Act of 1890. It allows any Urban **S.A.** which has adopted Part III. to establish or acquire lodging-houses for the working classes outside their district, and any Rural **S.A.**, with the consent of the County *Council, to adopt Part III.* either for the whole or part of their

district. In giving or withholding consent the County Council shall have regard to the area proposed, to the necessity for accommodation for the housing of the working classes in that area; to the probability of such accommodation being provided without the adoption of the said Part; and to the liability which will be incurred by the rates, and to the question whether it is, in all the circumstances, prudent to adopt the said Part.

An Urban S.A., with the consent of the L.G.B., and a Rural S.A. with the consent of the County Council, may lease any land acquired by them under and for the purposes of Part III. to any lessee for the purpose and under the condition that the lessee will carry the Act into execution by building and maintaining on the land lodging-houses within the meaning of the Act.

Section 6 defines the powers of the County Council to act in default of a Rural Council.

Compensation questions which may arise shall in default of agreement be determined by a single arbitrator to be appointed and removable by the L.G.B.

The Housing of the Working Classes Act, 1903, extends the maximum period for the repayment of loans raised for the purposes of these Acts to 80 years (from 60), leaving the actual period for repayment, subject to this limitation, to be determined with the sanction of the L.G.B.

The Board propose as a general rule to allow the full term of 80 years for the repayment of loans for the purchase of freehold land, and 60 years for the repayment of loans for the erection of buildings, where the circumstances are such that this may properly be done.

The powers given to the Board to direct a local inquiry to be held, and a report made to them as to the correctness of the official representation (when the S.A. has taken no action) are supplemented by s. 4 (1) of the 1903 Act. If, on report made to them after inquiry, they are satisfied that a scheme ought to have been made for the improvement of the area to which the inquiry relates, or some part thereof, they can order the S.A. to make such a scheme (under either Part I., or Part II.)

The Order of the Board is enforceable by mandamus.

Section 4 (2) provides that any 12 or more ratepayers of the district shall have the same right of appeal, under s. 16 of the 1890 Act, as is given to the 12 or more ratepayers who have made complaint to the M.O.H. mentioned in that section.

The advertisements of an improvement scheme under Part I. may be published for three consecutive weeks at any period of

the year, and the prescribed notices may be served during the 30 days next following the date of the last publication of the advertisement.

Section 8 concerns procedure for obtaining closing orders in regard to insanitary houses.—Where a **S.A.** desires to obtain a closing Order it was necessary under s 32 of the 1890 Act, first to give notice to the owner or occupier of the house to abate the nuisance. S 8, 1903, dispenses with this notice as regards any dwelling-house which, in the opinion of the **S.A.**, is either (*a*) not reasonably capable of being made fit for human habitation, or (*b*) is in such a state that its occupation should be immediately discontinued.

A more speedy and efficacious way of obtaining possession of a house in respect of which a closing Order has been made than that provided by s. 32 (3) of the 1890 Act is afforded by s. 10, 1903. Whatever the value or rent of the house, the **S.A.** may proceed either under Sections 138 to 145 of the County Courts Act, 1888, or under the Small Tenements Recovery Act, 1838. The expenses of these proceedings can be recovered from the owner under the Summary Jurisdiction Acts.

S. 11 (1) empowers the **S.A.**, if they provide lodging houses under Part III., or if they supply accommodation under the Housing Acts or under any scheme made in pursuance of those Acts, to provide and maintain, in connection therewith, any building adapted for use as a shop, any recreation grounds, or other buildings or land which, in the opinion of the Board, will serve a beneficial purpose in connection with the requirements of the persons for whom the lodging-houses or dwelling accommodation are provided. The consent of the Board is required to the exercise of these powers, and they may require statutory provisions of control.

Service of notices. The service of notices and other documents is facilitated by s. 13.

Sale of Food and Drugs Act, 1875.—This Act defines "food" as including every article used by man for food or drink, except water and drugs; and "drugs" as including medicine for external as well as internal use (s. 2). "No person shall mix, colour, stain, or powder (or order or permit any other person to mix, colour, stain, or powder) any article of food with any ingredient or material so as to render the article injurious to health, with intent that the

garine cheese," which must be clearly marked on the package in black letters not less than half an inch long. Every maker of margarine and margarine cheese shall keep a register as to quantity and destination of his consignments, and he shall submit to inspection (s. 7). The fat of margarine must not contain more than 10 per cent. of butter fat (s. 8), and condensed milk of all kinds may only be sold when clearly described on the label. A person selling milk on any highway must have conspicuously marked on the vehicle his name and address.

Penalties for wilful obstruction of officers in the course of their duties in food sampling and for offences under the Acts are, for the first offence, sums not exceeding £20, and for subsequent offences, £50 and £100; but proceedings may not be instituted after the expiration of 28 days from the time of purchase. A warranty is not available as a defence unless a copy has been sent to the purchaser within seven days of service of the summons, with a written notice stating that reliance will be placed on it, and specifying the name and address of the warrantor.

These Acts are directed not only against fraudulent dilution, abstraction and substitution, but also against injury to health, and the sampling and analysis should be guided by consideration of both points. In the case of beer the risk of lead contamination from pewter pipes has long been known, but that of arsenic was overlooked until 1900.

The **Margarine Act, 1887**, defines "butter" as made exclusively from milk, or cream, or both, with or without salt or other preservative, or added colouring matter. "Margarine" includes all substances, whether compounds or otherwise, prepared in imitation of butter, whether mixed with butter or not (s. 3). Every package of margarine must be so marked, in *capital* letters not less than $\frac{3}{4}$ inch square, and in *shops*, by labels with capital letters not less than

$1\frac{1}{2}$ in. square). All margarine factories must be registered with the Authority appointing the Public Analyst of the district (s. 9). Officers authorised under the Sale of Food and Drugs Acts may take samples of butter (or substances purporting to be butter which are exposed for sale and not marked as margarine) without going through the form of purchase required by that Act, but otherwise complying with its provisions as to dealing with the samples (s. 10). Any such substance not being marked as margarine is to be presumed to be exposed for sale as butter. The vendor is absolved if he proves that he bought the article with a written warranty, and sold it, in the same state as when bought, believing it to be butter. The penalty for a first offence is a fine not exceeding £20.

Sale of Horseflesh, etc., Regulation Act, 1889. The flesh of horses, asses, or mules must not be sold or kept for sale for human food, except in a shop or stall over or upon which is placed conspicuously, in legible characters four inches long, an announcement that horseflesh is sold there. If otherwise, the **M.O.H.** or inspector may seize the meat and carry it before a magistrate, who may order as to its disposal as he thinks fit; and the offender is liable to penalty. These conditions apply to such flesh cooked or uncooked, and alone or mixed with other substances. It is illegal to supply horseflesh for human food to a purchaser asking for other meat, or for a compounded article not usually made of horseflesh.

The Rivers Pollution Prevention Act, 1876, deals separately with (*a*) solid matters, (*b*) sewage, (*c*) trade effluents, and (*d*) mining effluents.

(*a*) No solid refuse of any kind must be put into any stream, so as to interfere with its due flow or to pollute its waters (s. 2).*

(*b*) No solid or liquid sewage matter must be passed into any stream; but as regards conditions in existence prior to 1876 no offence is committed under

* *See also* Public Health Acts Amendment Act, 1890 (p. 500)

this Act if it is shown that the best practicable and available means are being used to render harmless the sewage entering the stream (s. 3).

(*c*) No poisonous, noxious, or polluting liquid from any factory or manufacturing process must be passed into any stream. The saving clause as to conditions existent prior to 1876 is repeated here (s. 4).

(*d*) No solid matter from mines must be put into any stream so as prejudicially to affect its flow; nor must any poisonous, noxious, or polluting solid or liquid matter from mines be passed into any stream, other than water in the same condition in which it has been raised or drained from such mine (s. 5).

Proceedings may be instituted, in respect of pollution of streams by sewage or solid matters, by any private person or **S.A.** aggrieved (s. 8); but in respect of manufacturing or mining effluents **S.A.'s** only can take action, and subject to the approval of the **L.G.B.** The Board, in giving or withholding consent, shall have regard to the industrial interests involved, and the circumstances and requirements of the locality. They shall not give their consent to proceedings by the **S.A.** of a district which is the seat of any manufacturing industry, unless they are satisfied, after due inquiry, that means for rendering harmless the effluents from such manufacturing processes are reasonably practical and available, and that no material injury to the interests of such industry will be caused by the proceedings (s. 6). Any person interested may call the attention of the **S.A.** to pollution by manufacturing or mining effluents, and, if the **S.A.** refuse to move, may appeal to the **L.G.B.**, and the Board may, after due inquiry, direct the Authority to take proceedings (s. 6).

The **S.A.** must afford facilities for admitting trade effluents into sewers, unless they would prejudicially affect the sewers or interfere with the disposal of the

sewage, or be injurious in a sanitary point of view, from their temperature or otherwise, or unless the sewers are only large enough for the ordinary requirements of the district (s. 7).

[S. 14 of the Local Government Act, 1888, confers upon County Councils the powers of **S.A.'s** under the Rivers Pollution Prevention Act; and enables the **L.G.B.** to form a joint committee representing all the administrative counties through or by which a river, or any specified portion of a river, or any tributary thereof passes, and to confer upon the joint committee all or any of the powers of a **S.A.** under the Act.]

The Royal Commission on Sewage Disposal recommended in 1903 the formation of River Boards throughout the country composed of joint committees of County Councils for the purpose of properly enforcing the R.P.P. Act. Such Boards have the advantage of jurisdiction over the whole of a drainage area and are sufficiently large to secure the appointment of skilled officers. Some have extended powers under special Acts. Many methods are now available for the treatment of sewage at moderate cost, in such manner as to deprive it of most, if not all, of its impurities, leaving an effluent which may be passed into streams without material ill effect. As to trade pollutions, until recently comparatively little had been done. The difficulties, both legal and sanitary, are far greater than in respect of domestic or town sewage. Now, however, the treatment of sewage mixed with trade effluents is being practically dealt with and presents less difficulty where manufacturers adopt reasonable means for removing the solids, equalising the discharge, and, when necessary, neutralising the trade effluent.

A short explanatory Act (R.P.P. Act, 1893) removes a technical difficulty liable to be raised by **S.A.'s** *seeking to evade* their responsibilities under s. 3.

Canal Boats Act, 1877.—The term "canal" includes all navigable waters, tidal or otherwise, within the body of a county, and the term "canal boat" includes every vessel, however propelled, used for conveyance of goods along such waters, but does not include a ship registered under the Merchant Shipping Act, unless the **L.G.B.** orders otherwise. No canal boat must be occupied as a dwelling unless it is registered under this Act, and then only by the number of persons of the age and sex for which it is registered (s. 1). The registration authority must be a **S.A.** whose district abuts on the canal on which the boat is intended to ply; and the boat must be registered as belonging to some place which is within the said district, and which is also within a school district (s. 7). Upon registration two certificates must be given to the owner, identifying the owner and the boat, and stating the place to which it belongs, and the number, age, and sex of persons allowed to dwell in the boat. The master of the boat must carry one of these certificates. Every registered boat must have conspicuously painted upon it the registered number, the place to which it belongs, and the word "registered" (s. 3). If any person on a canal boat is suffering from an infectious disease, the **S.A.** of the place where the boat is shall adopt such precautions as appear necessary, upon the certificate of the **M.O.H.** or other legally qualified practitioner; and may remove such sick person and exercise the other powers conferred by the Public Health Act in this respect; and may detain the boat as long as is necessary for cleansing and disinfecting (s. 4). If any person duly authorised by the **S.A.** has reason to suspect any contravention of the Act, or that a person on board is suffering from an infectious disease, he may enter the boat for the purpose of inspection between 6 a.m. and 9 p.m., and may require the master

of the boat to afford him facilities for so doing, and to produce the certificate of registry of the boat (s. 5).

The second section directs the **L.G.B.** to make regulations (i.) for the registration of canal boats, (ii.) for lettering, marking, and numbering such boats; (iii.) for fixing the number, age, and sex of persons who may be allowed to dwell in a canal boat, having regard to the cubic space, ventilation, separation of the sexes, general healthiness, and convenience of accommodation; (iv.) for promoting cleanliness and habitable condition of such boats; and (v.) for preventing the spread of infectious disease by canal boats.

Such regulations were accordingly issued by the **L.G.B.** in 1878, and the following is a summary of their principal sanitary provisions:—

> There must be at least one dry, clean, weatherproof cabin, in good repair. An after-cabin intended to be used as a dwelling must contain not less than 180 cubic feet of free air space, and a fore-cabin 80 cubic feet; every such cabin must have means of ventilation besides the door, and must be so constructed as to provide adequate sleeping accommodation. One cabin must contain a stove and chimney. The boat must be furnished with suitable storage for three gallons of water. If intended to be ordinarily used for foul cargoes, the hold must be separated from any inhabited cabin by a double bulkhead with an interspace of four inches, and the bulkhead next the cargo must be water-tight. Not less than 60 cubic feet of air space must be allowed for each person over twelve years of age, and not less than 40 cubic feet for each person under that age. In "fly-boats" worked by shifts, a cabin occupied at the same time by two persons must have a capacity of 180 cubic feet. A cabin in which a married couple sleep must not be occupied at the same time by any other male above 14, or female above 12 years of age. Males above 14 and females above 12 years of age must not occupy the same sleeping cabin at the same time, but reservation is made for married couples, and also (under certain conditions) in respect of boats constructed prior to 1878. The interior of the cabin must be repainted every three years, and must be kept clean. Bilge water must be pumped out daily. The master of

the boat must at once notify the occurrence of any case of infectious disease on the boat to the **S.A.** of the district through which the boat may be passing, and also to the **S.A.** of the place of destination; he must also inform the owner, who is required to notify to the **S.A.** of the place to which the boat belongs. If the boat is detained by the **S.A.** for purposes of disinfection, the **S.A.** must obtain a medical certificate that the boat has been cleansed and disinfected, and must give it to the master.

The Canal Boats Act, 1884, amends the 1877 Act in certain details, and makes it incumbent upon every **S.A.** through whose districts any canal passes to enforce the provisions of the Act and Regulations, and to make an annual report upon the subject to the **L.G.B.*** The Board is required to make inquiries from time to time (by an inspector or inspectors specially appointed for the purpose) as to the working of the Acts and Regulations, and to report annually thereon to Parliament.

The Dairies, Cowsheds, and Milkshops Order of 1885 was made by the Privy Council under s. 34 of the Contagious Diseases (Animals) Act of 1878. An amending Act (C.D.A. Act, 1886) transferred to the **L.G.B.** the powers of the Privy Council under this section, and the D.C. and M. Amending Order, 1886, substituted the Board for the Privy Council and remedied certain omissions in regard to penalties, giving the Order the force of law. The D.C. and M. Order of 1899 amended the previous Orders by including tuberculosis among the infective diseases on the occurrence of which milk should not be sold under s. 15. The effect of the three Orders is to throw upon every **S.A.** the duty of supervising

* This report has to be drawn up in prescribed form and must include particulars as to registration, notification of change of master, certificate, marking of boat, overcrowding, separation of sexes, cleanliness, ventilation, painting, provision of water cask, removal of bilge water, notification of infectious disease, and admittance of inspector.

the milk trade in their district, and of carrying out certain general regulations prescribed by the Orders. These duties are common to all districts alike, but any **S.A.** may arm itself with further powers by making Regulations under s. 13, having the force of bye-laws. The chief provisions of the Orders are summarised below: –

Section 6. (1) It shall not be lawful for any person to carry on . . . the trade of cowkeeper, dairyman, or purveyor of milk unless he is registered as below. (2) Every **S.A.** shall keep a register of such persons, and shall from time to time revise and correct the register. (3) The **S.A.** shall register every such person, but registration shall not be deemed to authorise such person to occupy as a dairy or cowshed any particular building, or preclude proceedings. (4) The **S.A.** shall from time to time give public notice of registration being required, and of the mode of registration. (5) A person who carries on the trade of cowkeeper or dairyman for the purpose only of making and selling butter or cheese, or both, and who is not also a purveyor of milk, need not be registered. (6) A person who sells milk of his own cows in small quantities to his workmen or neighbours for their accommodation need not, by reason thereof, be registered.

Section 7. (1) It shall not be lawful to begin to occupy as a dairy or cowshed any building not so occupied at the commencement of this Order until provision is made, to the reasonable satisfaction of the **S.A.**, for the lighting and ventilation, including air-space, and the cleansing, drainage, and water-supply; or (2) without first giving one month's notice in writing to the **S.A.**

Section 8. It shall not be lawful to occupy as a dairy or cowshed any building—whether so occupied at the commencement of this Order or not—if . . . . the

lighting and ventilation, including air-space, and the cleansing, drainage, and water-supply thereof, are not such as are necessary or proper (*a*) for the health and good condition of the cattle therein; (*b*) for the cleanliness of milk-vessels used therein for containing milk for sale; and (*c*) for the protection of the milk therein against infection or contamination.

Section 9. It shall not be lawful for any . . . . cowkeeper, or dairyman, or purveyor of milk, or occupier of a milkshop (*a*) to allow any person suffering from a dangerous infectious disorder, or having recently been in contact with a person so suffering, to milk cows or to handle vessels used for containing milk for sale, or in any way to take part or assist in the conduct of the trade . . . . so far as regards the production, distribution, or storage of milk; or (*b*) if himself so suffering, or having recently been in contact as aforesaid, to milk cows or handle vessels containing milk for sale, or in any way to take part in the conduct of his trade as far as regards the production, distribution, or storage of milk; until, in each case, all danger therefrom of the communication of infection to the milk or of its contamination has ceased.

Section 10. It shall not be lawful for any . . . . cowkeeper, dairyman, or purveyor of milk, or . . . . occupier of a milk store or milkshop, after the receipt of notice of not less than one month from the Local Authority calling attention to the provisions of this Article, to permit any water-closet, earth-closet, privy, cesspool, or urinal to be within, communicate directly with, or ventilate into, any dairy or any room used as a milk store or milkshop.

Section 11. It shall not be lawful for any . . . . cowkeeper, or dairyman, or purveyor of milk, or occupier of a milk store or milkshop, to use a milk store or milkshop in his occupation, or permit the

same to be used, as a sleeping apartment, or for any purpose incompatible with the proper preservation of the cleanliness of the milk store or milkshop, and of the milk-vessels and milk therein, or in any manner likely to cause contamination of the milk therein.

Section 12. It shall not be lawful for any . . . . cowkeeper, or dairyman, or purveyor of milk to keep any swine in any . . . . building used by him for keeping cows, or in any milk store or other place used by him for keeping milk for sale

Section 13. Any **S.A.** may make regulations. (*a*) for the inspection of cattle in dairies; (*b*) for prescribing and regulating the lighting, ventilation,* cleansing, drainage, and water supply, of dairies and cowsheds . . . ., (*c*) for securing the cleanliness of milk stores, milkshops, and milk-vessels used for containing milk for sale; and (*d*) for prescribing precautions to be taken by purveyors of milk, and persons selling milk by retail, against infection or contamination.

Section 14. The following provisions shall apply to regulations made by any **S.A.** under this Order — (1) Every regulation shall be published by advertisement in a newspaper circulating in the district. (2) The **S.A.** shall send to the **L.G.B.** a copy of every regulation at least a month before the date of operation. (3) The **L.G.B.** may at any time revoke any regulation if satisfied on inquiry that it is too restrictive or otherwise objectionable.

Section 15. The milk of a cow suffering from cattle-plague, pleuro-pneumonia, or foot-and mouth disease (*a*) shall not be mixed with other milk; (*b*) shall not be sold or used for human food; and (*c*)

* Where a minimum cubic space is specified for cowsheds in such Regulations, the L.G.B. have suggested 800 cubic feet per head, but in many districts a lower standard has been adopted.

shall not be sold or used for food of animals, unless it has been boiled. Tuberculosis is now included in this section under the D.C. and M.O. of 1899.

The following Model Regulations under section 13 of the Order have been drawn up by the L.G.B. for Dairies, Cowsheds and Milkshops.

Interpretation.

1. The expression "cowshed" includes any dairy in which milking cows may be kept, and the expression "cowkeeper" means any person following the trade of a cowkeeper or dairyman required to be registered under the Order of 1885.

For the Inspection of Cattle in Dairies.

2. Every occupier of a dairy wherein any cattle may be kept, and which the M.O.H., or the Inspector of Nuisances, or any other officer of the Council specially authorised by them in that behalf, may visit for the purpose of inspecting cattle, and every person for the time being having the care or control of any such dairy, or of any cattle therein, shall afford such officer all reasonable assistance that may, for the purpose of the inspection, be required by him.

For prescribing and regulating the Lighting, Ventilation, Cleansing, Drainage, and Water Supply of Cowsheds and Dairies.

Part I.

The regulations in this Part shall apply to cowsheds the cows from which are habitually grazed on grass land during the greater part of the year, and when not so grazed are habitually turned out during a portion of each day.

3. *Lighting.*—Every cowkeeper shall provide that every cowshed in his occupation shall be sufficiently lighted with windows, whether in the sides or roof thereof.

4. *Ventilation.*—Every cowkeeper shall cause every cowshed in his occupation to be sufficiently ventilated, and for this purpose to be provided with a sufficient number of openings into the external air to keep the air in the cowshed in a wholesome condition.

5. *Cleansing.*—(1) Every cowkeeper shall cause every part of the interior of every cowshed in his occupation to be thoroughly cleansed from time to time as often as may be so

necessary to secure that such cowshed shall be at all times reasonably clean and sweet.

(2) Such person shall cause the ceiling or interior of the roof and walls of every cowshed in his occupation to be properly limewashed *twice* at least in every year, that is to say, *once* during the month of May and *once* during the month of October, and at such other times as may be necessary.

Provided that this requirement shall not apply to any part of such ceiling, roof, or walls that may be properly painted, or varnished, or constructed of or covered with any material such as to render the limewashing unsuitable or inexpedient, and that may be otherwise properly cleansed.

(3) He shall cause the floor of every such cowshed to be thoroughly swept, and all dung and other offensive matter to be removed from such cowshed as often as may be necessary, and not less than *once* in every day.

6. *Drainage.*—(1) Every cowkeeper shall cause the drainage of every cowshed in his occupation to be so arranged that all liquid matter which may fall or be cast upon the floor may be conveyed by a suitable open channel to a drain inlet situate in the open air at proper distance from any door or window of such cowshed, or to some other suitable place of disposal which is so situate.

(2) He shall not cause or suffer any inlet to any drain of such cowshed to be within such cowshed.

7. *Water Supply.*—(1) Every cowkeeper shall keep in, or in connection with, every cowshed in his occupation a supply of water suitable and sufficient for all such purposes as may from time to time be reasonably necessary.

(2) He shall cause any receptacle which may be provided for such water to be emptied and thoroughly cleansed from time to time as often as may be necessary to prevent the pollution of any water that may be stored therein, and where such receptacle is used for the storage only of water he shall cause it to be properly covered and ventilated, and so placed as to be at all times readily accessible.

PART II.

The regulations in Part I., and also the following regulation, shall apply to all cowsheds other than those the cows from which are habitually grazed on grass land during the greater part of the year, and when not so grazed are habitually turned out during a portion of each day.

8. A cowkeeper shall not cause or allow any cowshed in his occupation to be occupied by a larger number of cows than

will leave not less than *eight hundred feet* of air space for each cow.

Provided as follows:—

(*a*) In calculating the air space for the purposes of this regulation, no space shall be reckoned which is more than *sixteen feet* above the floor; but if the roof or ceiling is inclined, then the mean height of the same above the floor may be taken as the height thereof for the purposes of this regulation.

(*b*) This regulation shall not apply to any cowshed constructed and used before the date of these regulations coming into effect, until two years after that date.

Part III.

9. In this Part the expression "dairy" means a dairy in which cattle are not kept.

10. *Lighting.*—Every cowkeeper shall provide that every dairy in his occupation shall be sufficiently lighted with windows, whether in the sides or roof thereof.

11. *Ventilation.*—Every cowkeeper shall cause every dairy in his occupation to be sufficiently ventilated, and for this purpose to be provided with a sufficient number of openings into the external air to keep the air in the dairy in a wholesome condition.

12. *Cleansing.*—(1) Every cowkeeper shall cause every part of the interior of every dairy in his occupation to be thoroughly cleansed from time to time as often as may be necessary to secure that such dairy shall be at all times reasonably clean and sweet.

(2) He shall cause the floor of every such dairy to be thoroughly cleansed with water at least *once* in every day.

13. *Drainage.*—(1) Every cowkeeper shall cause the drainage of every dairy in his occupation to be so arranged that all liquid matter whcih may fall or be cast upon the floor may be conveyed by a suitable opening channel to the outside of such dairy, and may there be received in a suitable gully communicating with a proper and sufficient drain.

(2) He shall not cause or suffer any inlet to any drain of such dairy to be within such dairy.

14. *Water Supply.*—(1) Every cowkeeper shall cause every dairy in his occupation to be provided with an adequate supply of good and wholesome water for the cleansing of such dairy and of any vessels that may be used therein for containing milk, and for all other reasonable and necessary purposes in connection with the use thereof.

(2) He shall cause every cistern or other receptacle in

which any such water may be stored to be properly covered and ventilated, and so placed as to be at all times readily accessible.

(3) He shall cause every such cistern or receptacle to be emptied and thoroughly cleansed from time to time as often as may be necessary to prevent the pollution of any water that may be stored therein.

FOR SECURING THE CLEANLINESS OF MILK-STORES, MILK-SHOPS, AND OF MILK-VESSELS.

15. *Cleanliness of Milk-stores and Milk-shops.* — Every occupier of a milk-store or milk-shop shall cause every part of the interior of such milk-store or milk-shop to be thoroughly cleansed from time to time as often as may be necessary to maintain such milk-store or milk-shop in a thorough state of cleanliness.

16. *Cleanliness of Milk-vessels.* — (1) Every cowkeeper shall from time to time, as often as may be necessary, cause every milk vessel that may be used by him for containing milk for sale to be thoroughly cleansed with steam or clean boiling water, and shall otherwise take all proper precautions for the maintenance of such milk-vessel in a constant state of cleanliness.

(2) He shall, on every occasion when any such vessel shall have been used to contain milk, or shall have been returned to him after having been out of his possession, cause such vessel to be forthwith so cleansed.

FOR PRESCRIBING PRECAUTIONS AGAINST INFECTION OR CONTAMINATION OF MILK.

17. (1) Every purveyor of milk or person selling milk by retail shall take all reasonable and proper precautions, in and in connection with the storage and distribution of the milk, and otherwise, to prevent the exposure of the milk to any infection or contamination.

(2) He shall not deposit or keep any milk intended for sale—

(*a*) in any room or place where it would be liable to become infected or contaminated by impure air, or by any offensive, noxious, or deleterious gas or substance, or by any noxious or injurious emanation, exhalation, or effluvium; or

(*b*) in any room used as a kitchen or as a living room; or

(*c*) in any room or building, or part of a building,

communicating directly by door, window, or otherwise with any room used as a sleeping room, or in which there may be any person suffering from any infectious or contagious disease, or which may have been used by any person suffering from any such disease and may not have been properly disinfected; or

(*d*) in any room or building or part of a building in which there may be any direct inlet to any drain.

(3) He shall not keep milk for sale, or cause or suffer any such milk to be placed, in any vessel, receptacle, or utensil which is not thoroughly clean.

(4) He shall cause every vessel, receptacle, or utensil used by him for containing milk for sale to be thoroughly cleansed with steam or clean boiling water after it shall have been used, and to be maintained in a constant state of cleanliness.

(5) He shall not cause or suffer any cow belonging to him or under his care or control to be milked for the purpose of obtaining milk for sale—

(*a*) unless, at the time of milking, the udder and teats of such cow are thoroughly clean; and

(*b*) unless the hands of the person milking such cow, also, are thoroughly clean and free from all infection and contamination.

PENALTIES.

18. Every person who shall offend against any of the foregoing regulations shall be liable for every such offence to a penalty not exceeding *five pounds*, and in the case of a continuing offence to a further penalty not exceeding *forty shillings* for each day after written notice of the offence from the Council.

Provided, nevertheless, that the Justices or Court before whom any complaint may be made or any proceedings may be taken in respect of any such offence may, if they think fit, adjudge the payment as a penalty of any sum less than the full amount of the penalty imposed by this regulation.

The Public Health (London) Act, 1891, forms a sanitary code for London, and includes (with many important additions and amendments) the main provisions of the Public Health Acts and the Infectious Diseases Notification and Prevention Acts. A brief summary of the principal points of divergence from the Acts named above is appended.

Water supply.—Absence of proper water supply, or of proper fittings, is held to render a house unfit for habitation. A new house must not be occupied until the **S.A.** grant a certificate that it has a proper water supply. A water company cutting off the supply of any house must give immediate notice to the **S.A.** For closure of polluted wells, etc., the **S.A.** have only to satisfy the Court that the water is "so polluted, or likely to be so polluted, as to be injurious or dangerous to health."

Closets.—A new house must have "one or more water closets, as circumstances may require," with proper water supply and trapped soil-pan, and other accessories. The same applies to all houses, irrespective of date, under notice from the **S.A.** Substitution of privies or earth closets is only permissible if the available sewerage or water supply is insufficient for a water-closet. Penalties are prescribed for (*a*) wilfully injuring any drain or closet or water supply in connection therewith; (*b*) discontinuing any such water supply without lawful authority; and (*c*) so constructing or repairing a water-closet or drain that it is a nuisance or injurious to health.

Scavenging.—The **S.A.** must cleanse streets, footpaths, cesspits, earth-closets, privies, and cesspools. They must remove house-refuse at proper intervals; and trade refuse also, if required to do so, on payment. They may undertake the collection of manure and other refuse, on request; or may, by order, require periodical removal by the owner.

Cellar Dwellings.—No underground room not let or occupied separately as a dwelling before January 1st, 1892, can be so let or occupied, unless

(*a*) Every part is seven feet high, and at least three feet above the level of the adjoining ground; but if the outside area is six feet wide, or if its width is not less than the depth of the floor below ground-level,

then only one foot of the height need be above the ground-level.

(*b*) Every wall has a damp-course, and if in contact with the soil, is effectually secured from damp from the soil.

(*c*) There is an open area outside along the whole frontage, four feet wide in every part, and six inches below the floor-level. It may be crossed by steps, but not opposite a window.

(*d*) The area and the soil immediately below the room are effectually drained.

(*e*) The hollow space (if any) below the floor is ventilated to the outer air.

(*f*) Any drain under the room is made of gas-tight pipe.

(*g*) The room is effectually secured against the rising of any effluvia or exhalation.

(*h*) There is proper water-closet and ashpit accommodation.

(*i*) There is effectual ventilation.

(*j*) There is a fire-place, with chimney.

(*k*) There are one or more windows opening directly into the open air; the window-area being at least one-tenth of the floor area, at least half made to open, and in each case opening to the top.

The same conditions apply to underground rooms occupied separately as dwellings before January 1st, 1892; but the **S.A.**, either by general regulations or upon special application by the owner, may modify any conditions newly imposed by this Act which involve structural alteration of the building.

Keeping of animals.—Swine must not be kept within forty yards of a street or public place, nor be allowed to stray in any public place. A Court may prohibit the keeping of any animal in any specified place shown to be unfit for the purpose.

Offensive trades.—None of the following must be

established anew in London :—Blood-boiling, bone-boiling, manure manufacture, soap-boiling, tallow-melting, or knacker's yard. Nor any of the following, without the sanction of the County Council :—Fell-monger, tripe-boiling, slaughtering of cattle or horses, or other business which the County Council may, with the approval of the **L.G.B.**, add to the list. Slaughter-houses and knackers' yards must obtain licences, issued by the County Council, lasting for one year only, but renewable at the discretion of the County Council. The same applies to cowsheds.

Notification is compulsory. The medical certificate must state the patient's full name, postal address, age, sex, whether attended in public or private practice ; if in hospital, the date of admission, and the place from which brought. The **M.O.H.** must, within twelve hours of receipt, send a copy of the certificate to the Metropolitan Asylums Board, and another to the head-teacher of the schools attended by the patient or by other inmates of the house. The Asylums Board must furnish to the County Council, and to every **M.O.H.**, such weekly returns of certificates so received by them as the County Council may prescribe. Any **S.A.** may, with the consent of the **L.G.B.**, add other dangerous infectious diseases to the list, temporarily or permanently, and the County Council have like power for the county as a whole.

Isolation.—A person who knows himself to be suffering from a dangerous infectious disease must not milk any animal, or pick fruit, or engage in any business in such manner as to be likely to spread the disease. He must not enter any public conveyance, nor must any other person place him, or convey him, in such.

Disinfection.—Every **S.A.** must provide disinfecting apparatus.

Mortuaries.—Every **S.A.** must provide a mortuary ;

the addition of a room for post-mortems is optional, unless ordered by the County Council. The County Council may provide other mortuaries wherein bodies may be kept for identification, and must provide proper accommodation for inquests.

Appointment of M.O.H. must not be for a limited period only. It is not terminable by the **S.A.** without the consent of the **L.G.B.** The **M.O.H.** must live in his district, or within a mile of the boundary. He must be qualified as stated on page 465.

Sanitary Inspectors appointed after January 1st, 1895 (if they have not held office as sanitary inspector during three consecutive years prior to that date in a London district or in an urban district outside London with a population of not less than 20,000) must hold a certificate of competence granted after examination by such body as the **L.G.B.** may from time to time approve.*

Default of S.A.—In the event of default of the **S.A.** with respect to the removal of any nuisance, the institution of any proceedings, or the enforcement of any bye-law, the County Council may act in their stead, and recover the expenses from the **S.A.** If the **L.G.B.** are satisfied, upon complaint from the County Council and after due inquiry, that the **S.A.** have made default in carrying out any part of this Act, they may order the **S.A.** to perform the duty within a specified time; and if this is not done, the order may be enforced by mandamus, or the **L.G.B.** may appoint the County Council to perform such duty, at the cost of the **S.A.**

Bye-laws.—The London County Council *must* make bye-laws—

(1) As to the time and manner of conveying offensive matters by road or water.

(2) As to the closure and filling up of cesspools

* Such examinations are now conducted and certificates issued by the Sanitary Inspectors' Examination Board.

and privies, removal and disposal of refuse, and duties of householders in facilitating removal of house-refuse.

(3) As to water-closets earth-closets, ashpits, cesspools, and receptacles for dung, and the proper accessories thereof in connection with new or old buildings.

They *may* also make bye laws as to the conduct of certain offensive trades, the buildings in which they are carried on, and the mode of application for sanction. These trades are fellmonger, tripe-boiler, slaughterer of cattle or horses; but other businesses may be afterwards added to the list.

Every London **S.A.** *must* make and enforce bye-laws relating to nuisances and keeping of animals, houses let in lodgings, and also the following:—

(1) For the prevention of nuisances arising from offensive matter running out of any manufactory, brewery, slaughter-house, knacker's yard, butcher's or fishmonger's shop, or dunghill, into any uncovered place, whether enclosed or not.

(2) For the paving of yards and open spaces in connection with dwellings.

(3) For securing cleanliness, and freedom from pollution, of tanks, cisterns, and other receptacles of drinking-water.

(4) For maintaining the efficiency of flush for water-closets.

The **S.A.** *may* also make bye-laws relating to ship-borne infectious cases, public conveniences, mortuaries, and inhabited tents and vans (p. 566).

The London Building Act, 1894, is a consolidation act amending various enactments relating to streets and buildings in the metropolis. The Act is divided into an introduction and fifteen parts, dealing with the formation and widening of streets, lines of building frontage, naming and numbering of streets, heights and construction of buildings, temporary, dangerous and neglected structures, sky-signs,

and a number of similar miscellaneous matters. Some powers under the Act, such, for instance, as respect wooden structures, and in relation to the removal of obstructions in streets, are to be exercised by the Borough Councils; otherwise the Act is administered by the London County Council.

The Infant Life Protection Act, 1897, requires that persons receiving for hire infants for the purpose of maintenance must give notice to the local authority (in London the County Council, elsewhere the Board of Guardians, except in Scotland, where it is the Parish Council), furnish particulars, and submit to inspection and supervision. The local authority may, by Order, require the removal of such infant to a workhouse or "place of safety," if it be kept in premises which are so unfit or so overcrowded as to endanger its health, or if it be kept by persons unfit to care for it, or who, by negligence, ignorance or other cause, endanger its health.

The Cleansing of Persons Act, 1897, gives power to **S.A.** to provide cleansing facilities free of charge (not to be considered as parochial relief or charity) to persons infested with vermin. In practice such cleansing includes a bath and disinfection of clothes.

CHAPTER XIX.

FACTORIES AND WORKSHOPS.

INCIDENTAL reference has been made in Chapters XVII. and XVIII. to the powers and duties of the **S.A.** with regard to industrial premises. Large additions are made by the Factory Act, and in stating these it will be convenient to refer briefly to some of the leading points in industrial hygiene, and to indicate generally the division of responsibility between the local and central authorities.

The Factory and Workshop Act, 1901, which applies to some 100,000 factories and 150,000 workshops, giving employment to about 5,000,000 workpeople, is administered chiefly by H.M. Inspectors of Factories, but also in important particulars by the **S.A.** The latter are charged with duties as to (1) sanitation of workshops (and, in certain particulars, factories also), (2) bakehouses, (3) home work, and (4) means of escape from fire. Many of these fall to the **M.O.H.,** upon whom are placed further duties of reporting.

Factories include (1) all places in which mechanical power is used in aid of the manufacturing process, and (2) the following, whether power be used or not: *print works*, *bleaching and dyeing works*, *earthenware works*, *lucifer match works*, *percussion-cap works*, *cartridge works*, *paper-staining works*, fustian-cutting works, *blast furnaces*, copper mills, *iron mills*, *foundries*, *metal and india rubber works*, paper mills, glass works, tobacco factories, letterpress printing works, bookbinding works, flax scutch mills, *electrical stations*. Those in italics are technical expressions, defined in the Act.

A *tenement factory* is one in which mechanical power is supplied to different parts of the same building occupied by different persons for the purpose of any manufacturing process or handicraft in such manner that these parts constitute in law separate factories.

Workshops include (1) the following, unless they are factories by reason of use of mechanical power:—hat works, *rope works, bakehouses* ("any places in which are baked bread, biscuits, or confectionery from the baking or selling of which a profit is derived"), *lace-warehouses, shipbuilding yards, quarries, pit-banks of* metalliferous mines, dry-cleaning works, carpet-beating works, and bottle-washing works.

(2) Premises (not being factories) in which manual labour is exercised by way of trade or for purposes of gain, in or incidental to the making, altering, repairing, ornamenting, finishing or adapting for sale of any article, *if the employer has the right of access or control.*

(3) *Tenement workshops:* that is, workplaces in which, "with the permission of or under agreement with the owner or occupier, two or more persons carry on any work which would constitute the workplace a workshop if the persons working therein were in the employment of the owner or occupier."

There may be several distinct factories or workshops, each comprising one or more rooms in different occupation, in the same building, which may also be used for dwelling or other purposes.

Domestic factories and *domestic workshops* are those carried on in private houses without use of mechanical power, where the only persons employed are members of the same family dwelling there. If any work certified by the Home Secretary to be dangerous is carried on they are treated as ordinary factories and workshops: otherwise they are, so far as sanitation is concerned, treated as ordinary *workshops*, except that the requirements as to general ventilation and drainage of floors do not apply.

The following, if carried on under conditions which would otherwise make the premises a domestic workshop, are exempted.

(1) Straw-plaiting, pillow-lace making, glove-making.

(2) Work done at irregular intervals and not furnishing the principal means of living to the family.

Men's workshops (those in which only males over 18 are employed) are exempted from several of the provisions of the Act, including those relating to general ventilation, temperature, drainage of floors, sanitary accommodation, lavatories, fans for removal of dust or fumes, and means of escape from fire.

Crown factories and workshops are excluded from the jurisdiction of the **S.A.**

Workplace is not defined, but has a wider meaning than workshop, and has been held to include any place where people assemble together to do work permanently: e.g. a stable and

stableyard where men were employed as cab-cleaners and horse keepers.

In *workshops and workplaces* the **S.A.** are primarily responsible for enforcing sanitary requirements generally, and means of escape from fire, and their officers have the same powers of entry, inspection, and legal proceedings as Inspectors of Factories. Certain sanitary requirements, however, more particularly those relating to temperature, fans for removal of dust and fumes, and those arising under the Factory Act (as distinguished from the powers of the **S.A.** under the P.H. Acts) with regard to sanitary accommodation, are enforced by the Factory Inspectors. The **S.A.** are required to keep a register of all workshops in their district. If the **M.O.H.** finds any woman, young person, or child employed in a workshop in which no abstract of the Factory Act is affixed, he is required to inform the Factory Inspector. The occupier of a new factory, workshop or laundry must notify the Factory Inspector, who, in the case of a workshop, forwards the notice to the **S.A.**

In *factories*, sanitation generally is enforced by the Factory Inspector, not by the **S.A.**, but the latter deal with means of escape from fire (in London this rests with the County Council), and sanitary accommodation (under the P.H. Acts only), and have special duties in connection with bakehouses and domestic factories.

If any act or default, punishable or remediable under the P.H. Acts but not under the Factory Act, is found by the Factory Inspector in a factory or workshop, he is to report it to the **S.A.**, who must make enquiry, take such action as may seem proper, and inform the Factory Inspector what has been done. If proceedings are not taken by the **S.A.** within a month, the Factory Inspector may institute proceedings in default, and recover from the **S.A.** any expenses not recovered from other persons, and not incurred in unsuccessful proceedings. If the **S.A.** fail generally to carry out their

duties with regard to factories, workshops or workplaces, the Home Secretary may authorise the Factory Inspector to act in default for a specified period, and the expenses not recovered from other persons may be recovered from the **S.A.**

The **M.O.H.** is required in his Annual Report to report specifically upon the administration with regard to workshops and workplaces, and to send a copy to the Home Secretary. A table issued by the **L.G.B.** for the guidance of the **M.O.H.** includes the items calling for statistical record.

Outside the Factory Act (which is directed to the protection of the workers), the **S.A.** are concerned with certain factories and workshops on public health grounds, as sources of smoke, poisonous fumes, trade effluents; as places where offensive trades or food manufacture needing control are carried on; as new buildings needing approval of plans, or old buildings in a dangerous state; or more indirectly as places in which infection may be spread from one person to another, or (as in laundries) infected articles may be handled.

Nor are these the only points claiming the attention of architects, builders, and **S.A.**'s in connection with plans for new factories and workshops. Others are strength of foundations and structure generally where heavy machinery is to be fixed; means of escape from fire; sanitary accommodation. Others, again, are the statutory requirements as to air-space, ventilation and warming; the surfaces of walls and ceilings must be such as to admit of due cleansing, and the proper construction of floors (soundness, impermeability, slope, drainage) is of importance in certain processes. In certain dangerous trades additional structural requirements arise, and in some the plans have also to be approved by the Chief Inspector of Factories.

Cleanliness.—Workshops and workplaces must be kept in a cleanly state; and a workshop, or any specified part thereof (in London, a workplace or domestic factory also), must be limewashed, cleansed, or purified when so required by notice from the **S.A.** on certificate of the **M.O.H.** or Sanitary Inspector that it is necessary for the health of the workers.

Factories must be kept in a cleanly state and

(subject to certain exceptions) either (*a*) limewashed every 14 months, or (*b*) painted with oil or varnished every 7 years, and washed with soap and hot water every 14 months.

For the cleaning of floors, etc., damp processes are preferable, as checking the production of dust.

Air-space. Factories, workshops and work-places must not be so overcrowded as to be dangerous or injurious to the health of the workers, and there must be at least 250* c.f. of air-space for each worker. The air space of each workroom must be stated in a notice affixed in the works.

A much larger air-space is required in certain dangerous trades, and in works where certain special exceptions are permitted—*e.g.* in match factories in which yellow phosphorus is used the minimum is 400 c.f., and height above 14 feet is not counted, and in engineering works exemption from routine annual limewashing is allowed if the air-space be 2,500 c.f. per head.

General Ventilation must be efficient in every workroom of a factory or workshop (other than a men's workshop), and any standard† fixed by the Home Secretary must be observed.

Air samples are usually taken at the breathing level, at points where work is carried on, and not in extreme corners or near to inlets or outlets, or close to persons or to sources of CO_2. In breweries, aerated water factories, bakehouses, etc., where CO_2 is given off by trade processes, allowance has to be made, and similarly where artificial lighting yields CO_2. As a rule it is well to make a parallel determination in the open air.

Mechanical ventilation by fans may be either on the plenum or vacuum system. The number, position, dimensions and speed of the fans are matters requiring expert knowledge; as a rule better results are obtained by large fans moving slowly

* 400 during overtime of women; 500 in underground bakehouses, 400 between 9 p.m. and 5 a.m. in other bakehouses with light other than electric, 400 in workshops (not domestic) used also as sleeping rooms.

† *e.g.* A limit of 9 vols. CO_2 per 10,000 in humid cotton cloth factories, and 600 c.f. fresh air per head per hour in other humid textile factories.

than by small fans at a high speed. Plenum is on the whole preferable, and offers facilities for warming, screening or humidifying the air when necessary. Exhaust ventilation calls for care in guarding against indraught through closets or other unsuitable channels. Paddle fans, which churn the air without changing it, are not to be regarded as means of ventilation, though the currents they cause may promote evaporation, and thus have some cooling effect. If reliance is placed on "natural" ventilation (whether by chimneys, open windows and doors, ventilators or shafts), supervision becomes necessary, especially in cold weather. In any case care should be taken to secure ventilation of all parts of the room, to avoid short-circuiting and direct draughts upon workers, and to provide adequately for both inlets and outlets.

Local ventilation, for removal of dust, gases, vapours or other impurities generated in the course of work, which are a nuisance or injurious to health, must be such as to render them harmless as far as possible.

Usually this involves exhaust ventilation, applied at or near the point of origin; and fans (or other efficient mechanical means) for the purpose are prescribed in certain dangerous processes, and can be required by the Factory Inspector in others. Exhaust ventilation may sometimes be secured by connection with flues or other heated shafts, but in general fans are required and need careful planning. The essentials are that the dust or fumes should be intercepted as near as possible to their source, and carried away from the workers, without entering the general air of the room: that the draught should be adequate for the purpose, and guided where necessary by hoods: and that the air-ducts should be kept clean and discharge at a suitable point, preferably in a closed dust-chamber. As a rule a downward draught is best, since it carries away the dust more readily. The efficiency of exhaust can be tested by anemometer, or by smoke, light dust, or fumes of ammonium chloride. In some instances standards are fixed, in terms of sectional area of openings and velocity at given points.

Other measures are the use of closed chambers or boxes, and as regards dust the adoption of wet processes, handling the dusty materials over gratings through which the dust can fall, cleanliness of premises and floors, and the use of overalls.

As a last resource respirators may be adopted, especially

where the occupation is intermittent, but there is difficulty in enforcing the systematic use of them, and most of them entail some physical discomfort if worn for long periods or in heavy work. The essentials in a respirator are that it should be light, simple, inexpensive, the filtering material readily renewed or cleaned; that it should be as little unsightly as possible; that it should arrest all dust, filter the whole of the inspired air, and prevent the rebreathing of expired air; and that it should offer the minimum resistance to the free passage of air without respiratory effort, and without becoming obstructed in use by moisture from the breath. A fold of cambric covering the mouth and nostrils is an efficient simple respirator. Many elaborate forms fail when tried under the actual conditions of the work for which they are proposed.

Some kinds of dust are directly infective, *e.g.* anthrax, tetanus, small-pox (among rag-sorters in paper works and elsewhere); others poisonous (*e.g.* lead, mercury); and others, again, mechanically injurious in varying degree. Similarly the wide variety of gases, fumes and vapours which arise in manufacturing processes and require removal include many which are directly poisonous (*e.g.* CO, CS_2, H_2S, SO_2, chlorine, nitrous and other acid fumes, AsH_3, lead, zinc and mercury fumes), and some which are harmful in other ways (*e.g.* steam) or offensive (organic effluvia).

Explosion may arise from ignition of inflammable dust or fumes mixed with air (*e.g.* ordinary gas, marsh gas (in coal mines), naphtha, coal dust, or celluloid borings.

Temperature.—In every workroom of a factory or workshop provision must be made for securing a reasonable temperature, and without interfering with the purity of the air of the room. This requirement is enforced by the Factory Inspector. Gas jets cannot be accepted as means of warming, nor must the ventilators be closed. Flueless stoves are objectionable, owing to the risk of adding sulphur compounds, CO, and other impurities to the air.

As a lower limit 60° F. is suitable for sedentary occupations involving little exertion, but active work can be carried on, indoors as well as in the open air, at lower temperatures. The upper limit is not easily defined, since in certain processes a high temperature is a trade necessity, while in others it is only accidental (*e.g.* from use of furnaces, consumption of gas, moving machinery, steam pipes), and calls for preventive measures such as free ventilation, screening off sources of heat, "lagging" of hot pipes and reducing their dimensions as far as practicable. In humid cotton cloth factories the prescribed precautions of the kind include whitewashing of the roof in

summer, and it is forbidden to raise the temperature artificially above 70° F., except so far as is necessary in humidifying.

If the air be dry enough, high temperatures can be borne, but as a matter of health as well as comfort high wet-bulb temperatures are to be avoided as far as possible, especially where the work is hard.

Humidity is expressly regulated in humid textile factories generally,* a limit being fixed for each dry-bulb degree: 88 % from 59° to 70°, decreasing thenceforward to 77·5 % at 80°, 69 % at 90°, and 64 % at 100°. In certain textile processes, however, a difference of 2° between wet and dry bulb is accepted at all temperatures. Hygrometers must be affixed in each room, and (except in cotton spinning) records kept of two (in cotton cloth factories three) daily readings at [7 to 8 a.m.], 10 to 11 a.m., and 3 to 4 p.m. The water used for humidification must either be taken from a pure source or be effectively purified; a water which gives off offensive gases of any kind on heating, or which absorbs from acid solution of $KMnO_4$ at 60° F. in 2 hours more than 0·5 mgr. of oxygen, may be regarded as unsuitable. In moist air the clothing becomes damp, and warmed ventilated cloak-rooms are obligatory in new humid cotton weaving factories.

Steam in excess arises incidentally in laundries, dyehouses, etc., and can be removed by exhaust ventilation or by introducing hot dry air.

Lighting is only regulated by the Factory Act as regards underground bakehouses (p. 556) and in certain dangerous trades. For artificial lighting electric light or ventilated gas burners are preferable, as they do not add to the impurity of the air or call for additional ventilation.

Floors have to be sound and impervious for the purpose of certain dangerous processes, and to be drained in wet processes generally (except in men's workshops) and especially in factory laundries.

Sanitary Accommodation is enforced by **S.A.'s** in both factories and workshops, in London and where s. 22 of the P. H. Acts Amendment Act of 1890 is in force (p. 500). Elsewhere the **S.A.** have other powers under s. 38 of the P.H. Act, 1875; but s. 9 of the Factory Act also applies, and the administration of

* Spinning and weaving factories in which the air is artificially humidified by steam jets or otherwise, in order to correct the dryness of the air, which beyond a certain limit interferes with the treatment of the fibre.

this (and of the order which interprets it) rests with the Factory Inspector alone.

Factory and Workshop Act, 1901: *s.* 9. "(*a*). Every factory and workshop must be provided with sufficient and suitable accommodation in the way of sanitary conveniences, regard being had to the number of persons employed or in attendance at the factory or workshop, and also where persons of both sexes are or are intended to be employed or in attendance, with proper separate accommodation for persons of each sex. (*b*). The Secretary of State shall, by special order, determine what is sufficient and suitable accommodation within the meaning of this section."

Sanitary Accommodation Order of February 4th, 1903.

"In pursuance of Section 9 of the Factory and Workshop Act, 1901, I hereby determine that the accommodation in the way of sanitary conveniences provided in a factory or workshop shall be deemed to be sufficient and suitable within the meaning of the said section if the following conditions are complied with and not otherwise:—

"1 In factories or workshops where females are employed or in attendance there shall be one sanitary convenience for every 25 females.

"In factories or workshops where males are employed or in attendance there shall be one sanitary convenience for every 25 males; provided that—

(*a*) in factories or workshops where the number of males employed or in attendance exceeds 100, and sufficient urinal accommodation is also provided, it shall be sufficient if there is one sanitary convenience for every 25 males up to the first 100, and one for every 40 after;

(*b*) in factories or workshops where the number of males employed or in attendance exceeds 500, and the District Inspector of Factories certifies in writing that by means of a check system, or otherwise, proper supervision and control in regard to the use of the conveniences are exercised by officers specially appointed for that purpose, it shall be sufficient if one sanitary convenience is provided for every 60 males in addition to sufficient urinal accommodation. certificate given by an Inspector shall b attached to the general register, and shall b at any time to be revoked by notice in writin the Inspector.

"In calculating the number of conveniences required by this order, any odd number of persons less than 25, 40, or 60, as the case may be, shall be reckoned as 25, 40, or 60.

"2. Every sanitary convenience shall be kept in a cleanly state, shall be sufficiently ventilated and lighted, and shall not communicate with any work-room except through the open air or through an intervening ventilated space; provided that in work-rooms in use prior to 1st January, 1903, and mechanically ventilated in such manner that air cannot be drawn into the work-room through the sanitary convenience, an intervening ventilated space shall not be required.

"3. Every sanitary convenience shall be under cover and so partitioned off as to secure privacy, and if for the use of females shall have a proper door and fastenings.

"4. The sanitary conveniences in a factory or workshop shall be so arranged and maintained as to be conveniently accessible to all persons employed therein at all times during their employment.

"5. Where persons of both sexes are employed, the conveniences for each sex shall be so placed or so screened that the interior shall not be visible, even when the door of any convenience is open, from any place where persons of the other sex have to work or pass; and, if the conveniences for one sex adjoin those for the other sex, the approaches shall be separate.

"6. This order shall come into force on the 1st day of July, 1903.

A. Akers-Douglas,
One of His Majesty's Principal
Secretaries of State.

"Home Office, Whitehall,
4th February, 1903."

Lavatories are required where any poisonous substance is used. For certain dangerous trades details are prescribed, *e.g.* that there shall be soap, nailbrushes, towels, and at least one basin (with water supply and waste pipe) for every 5 persons. In some, baths also are required. *Cloak-rooms* are obligatory in new humid cotton cloth factories, and where certain dangerous trades are carried on.

In certain rooms, *e.g.* where poisonous substances are so used as to give rise to dust or fumes, it is forbidden to take food or to remain during meal hours, and accommodation for meals *must* be provided elsewhere on the premises.

The dangers to health against which the above provisions are directed are obvious, but there are, of course, many others

of a different kind, not limited to employment under the Factory Act. Thus coal miners are liable to nystagmus from working in constrained positions, and to "beat hand" and "beat knee" (chronic inflammation due to local pressure); men working in compressed air to "caisson disease" if care be not taken to pass slowly from higher to lower pressures, through air-locks. Writer's cramp, housemaid's knee, the emphysema of performers on wind instruments, are other examples. Hernia or aneurism may be determined by violent exertion; carrying unduly heavy weights is injurious, and is indirectly prohibited as regards girls under 18 as a condition of special exception as to hours in fruit preserving. Sight may suffer from strain in fine work in inadequate light. Habitual exposure to weather in open-air occupations, and violent alternations of temperature in connection with furnaces or otherwise, present dangers of their own.

Means of Escape from Fire.—Factories built after 1891 and workshops built after 1895, must, if more than 40 persons are employed, have a certificate from the **S.A.** as to reasonable adequacy in this respect, specifying in detail the means provided. In older works with more than 40 hands the **S.A.** must see that reasonable provision is made, and if not, must require the owner by notice to carry out specified details in a specified time: any dispute to be settled by arbitration. The whole of a tenement factory or tenement workshop is counted as one. The **S.A.** may, subject to confirmation by the **L.G.B.,** make byelaws as to means of escape in any factories or workshops. In London these duties rest with the County Council.

Doors of workrooms must not during working hours be fastened so as not to be readily opened from inside; and in works built after 1895, doors of rooms in which more than 10 persons are employed must not open inwards.

Adequate means of escape are all the more essential where the nature of the manufacture entails special risk of fire. Alternative paths of escape are desirable (since the main line of exit may be readily involved in the fire) especially where large numbers are employed, and these paths should be obvious and kept clear of unnecessary obstruction.

Laundries are not technically factories or workshops, but are subject to the same requirements under the Act as regards sanitation. In addition in *factory* laundries, (*a*) fans are required for regulating the temperature of ironing-rooms, and for removing steam from washhouses; (*b*) stoves for heating irons must be sufficiently separated from the ironing-room, and gas-irons emitting noxious fumes must not be used; (*c*) floors must be kept in good condition and so drained as to allow the water to flow off freely.

Laundries in which the only persons employed are:

> (*a*) Inmates of a prison, reformatory, industrial school or other institution subject to inspection under any other Act, or (*b*) inmates of a religious or charitable institution, or (*c*) members of the same family dwelling there,

or in which not more than two persons dwelling elsewhere are employed, are exempted.

Bakehouses are factories or workshops, but subject to certain special requirements as below. *Retail bakehouses* are workshop bakehouses in which the articles baked are sold by retail only in a shop occupied therewith. *Underground bakehouses* are those in which any room used for baking or processes incidental thereto has its floor more than 3 feet below the footway of the adjoining street or ground adjoining or nearest to the room.

If a bakehouse is on sanitary grounds unfit for that use, a Court may, on application by the Factory Inspector or **S.A.**, impose a penalty and require the necessary alterations to be made. It must not contain or communicate directly with a closet, nor derive its water supply from a cistern supplying a w.c. A drain or pipe for carrying off fæcal or sewage matter must not have an opening in the bakehouse (thus any waste-pipe must be disconnected outside). The walls and ceilings of rooms, passages and staircases must be limewashed every 6 months; or receive 3 coats of oil-paint or varnish every 7 years, and be washed with hot water and soap every 6 months. A part of the same building, on the same level with the bakehouse, must not be used as a sleeping-room unless partitioned off from floor to ceiling, and having an external glazed window 9 square feet in area, $4\frac{1}{2}$ of which is made to open.

An underground bakehouse must not be used as such unless (*a*) it was so used on August 17th, 1901, and further (*b*) the **S.A.** has certified it to be suitable as regards construction, light, ventilation and in all other respects.

The administration of these special requirements in retail bakehouses (in London in all workshop bakehouses), and the certification of underground bakehouses, rests with the **S.A.**

In other cases the Factory Inspector and **S.A.** have concurrent powers.

A high standard of sanitation is needed in premises where food is manufactured, prepared, cooked or stored, including bakehouses, restaurant kitchens, ice cream premises, fish-shops, meat-shops, preserved meat works, confectionery works, dairies and milk-shops. The following summary, directed primarily to bakehouses, may serve to indicate generally the chief points needing attention.

Surfaces of floors, walls and ceilings to be hard, smooth, durable and impervious.

Floors to be laid to proper falls, and drained by proper channels to a gully outside.

Walls to be absolutely dry; failing this, to have an inner wall at least ½-inch thick, tied to the outer wall, but with 2-inch ventilated and drained intervening space.

Any drain beneath the floor to be gas and water-tight. All pipes and fittings to be efficient.

Minimum height 8 feet; minimum air-space 400 c.f. per head and 1,500 c.f. in all, clear of ovens, machinery, and stored goods

Efficient lighting: where practicable natural light only; among artificial lights electric is preferable, or if gas is necessary, incandescent burners protected from dust and ventilated to remove fumes.

Ventilation, by fan if necessary, ensuring constant and sufficient change of air without draughts, and a temperature not ordinarily exceeding 60° F., or 80° F. at any time except within half-an-hour after "drawing" an oven.

Oven furnaces to have efficient flues to carry away fumes.

An outlet for heat and steam immediately before and above the oven door. Oven doors and outer doors of furnaces to fit closely. Proving ovens to be efficiently ventilated. If gas is used for heating, means of removing fumes Hoods and ducts leading to the open air, over stoves and ranges.

Strict cleanliness of premises and appliances.

Water supply, with jet and hose, for washing floors, cisterns (if any) to be of proper construction, with dust-tight covers, and kept clean.

Tables, benches, dough troughs, etc., to be freely movable on casters.

Any necessary shelves to be fixed 2 inches away from walls, but unnecessary woodwork on walls to be avoided.

Covered metal boxes for refuse.

Suitable provision, outside the workroom, for storage of food materials (*milk* in clean covered vessels, in a cool place); storage

of fuel; deposit of clothing not in use; lavatory; sanitary accommodation.

Home work of certain kinds* defined by order of the Home Secretary is under special control. The employer must keep lists of the names and addresses of the outworkers, and send copies to the **S.A.** of his district on or before February 1st and August 1st of each year, in a prescribed form. If any such addresses are outside the area of the **S.A.**, particulars of them must be sent by the **S.A.** to the **S.A.** concerned. If the home premises are injurious or dangerous to the health of the workers, the **S.A.** may prohibit the employer from giving out work to be done there.

If an inmate of the house is suffering from a notifiable infectious disease (even if he has been removed) the **S.A.** may by order prohibit the employer from giving out work to be done in that house or in any specified part of it, during a specified term. This power applies only to the classes of work named in the first part of the list. In emergency it may be exercised by two or more members of the **S.A.** on the advice of the **M.O.H.** The order may be subject to conditions as to disinfection or other precautions.

In case of scarlet fever or small-pox, an employer giving out work or wearing apparel is subject to penalty, apart from any order from the **S.A.** as above, unless he proves that he was not aware of the illness and could not reasonably have been expected to become aware of it.

Industrial Poisoning.—"Every medical prac-

* The making, cleaning, washing, altering, ornamenting, finishing, and repairing of wearing apparel and any work incidental thereto; the making, ornamenting, mending and finishing of lace and of lace curtains and nets; cabinet and furniture making and upholstery work; fur-pulling.

The making of electro-plate; files; iron and steel cables and chains; iron and steel anchors and grapnels; cart gear, including swivels, rings, loops, gear buckles, mullin bits, hooks, and attachments of all kinds; locks, latches and keys.

titioner attending on or called in to visit a patient whom he believes to be suffering from lead, phosphorus, arsenical or mercurial poisoning, or anthrax, contracted in a factory or workshop, shall . . . send to the Chief Inspector of Factories, at the Home Office, London, a notice stating the name and full postal address of the patient and the disease from which in the opinion of the medical practitioner the patient is suffering." A fee of 2s. 6d. is allowed. The *employer* must notify such cases to the Inspector of Factories and to the Certifying Surgeon.

Lead poisoning arises in a number of industries, from the materials or appliances used. Owing to more stringent precautions the number of reported cases in the United Kingdom fell yearly, from 1,258 in 1899, to 597 in 1904, the six years' totals being—

*White Lead .. .	1,314	Ship-building . . .	177
*Earthenware & China	845	Printing . .	114
Coach-building . .	386	*Tinning & Enamelling of Metals	104
*Paints and Colours	304	Other	1,337
*Smelting of Metals ..	249		
*File Cutting	198		
*Electrical Accumulators	191	Total	5,019

Those marked * are under special rules or regulations as dangerous trades. The great danger is that of inhalation or swallowing of dust, but there is also risk from carrying unwashed hands to the mouth, from eating or using tobacco while at work, and in some industries from fumes containing lead. The chief preventive measures, apart from those directed against dust and fumes (p 550), are the substitution of materials free from lead or containing it only in an insoluble and comparatively harmless form, facilities for washing and due use of them, overalls in dusty processes, periodical medical examination of workers, and exclusion of persons found to be su
Women appear to be more susceptible than men, a
ployment of children and even of young persons
forbidden in certain lead processes, as less atte
cautions can be expected from them.

The figures given above are those for industries

each including a variety of processes involving very different degrees of risk: thus in pottery processes the incidence is much greater among dippers and ware-cleaners, who handle the glaze before it is fired; and in the processes named much depends upon the nature of the materials handled, the frequency and duration of employment, the conditions of work, including observance of precautions, and upon the age and sex of the workers. These considerations are material in estimating the statistical value of attack-rates or mortality rates, in all industrial diseases and not merely as regards plumbism. A further necessary consideration is the character of attack, which varies greatly as regards the nature, site, and severity of symptoms, and shades off into constitutional conditions which can hardly be regarded as poisoning or disease, and may only be revealed by large statistics showing greater tendency to more remote affections, such as the kidney disease and gout which are found from mortality returns to be more common among lead-workers than others.

Phosphorus poisoning is now rare, stringent precautions being in force in the lucifer match factories in which yellow phosphorus is used. Its characteristic manifestation is necrosis of the jaw, arising in connection with carious teeth: it rarely occurs until the employment has been long continued, and there is some reason to suppose that it is dependent upon a constitutional change predisposing to local attack. Substitutes for yellow phosphorus have been found in red phosphorus (a harmless form), sesquisulphide of phosphorus, and other chemicals. Other precautionary measures in force are the use of closed vessels for phosphorus, separation of phosphorus processes from each other and from the rest, free general ventilation, exhaust ventilation, washing facilities and systematic use of them, overalls, and periodical examination by a dentist (with power to forbid employment), in order to secure soundness of teeth.

The reported attacks in 1899-1904 were 8, 3, 4, 1, 0, 1.

Arsenical poisoning arises chiefly in connection with paints and colours and in chemical works, or exceptionally from the evolution of arseniuretted hydrogen in metallurgical processes. In 1900-1904, 49 attacks were reported.

Mercurial poisoning is met with in industries in which mercury or a mercurial salt is used: including the making of thermometers and other scientific instruments, furriers' work (in "carrotting") and chemical works. Formerly it was observed among "water gilders" employed in "silvering" mirrors by means of mercury. In addition to salivation, alimentary disturbances and cachexia, there are peculiar fine tremors of the

hands and arms, with occasional pains in the joints. In 1899-1904, 56 attacks were reported.

Anthrax was reported in 261 instances in 1899-1904.

INDUSTRY.	ATTACKS	DEATHS
Wool, Worsted ...	88	23
Horsehair, Bristles ...	70	17
Hides, Skins ...	86	21
Other ...	17	6

Six, all fatal, and all in the woollen and worsted trade, were of the "internal" kind. Among "external" cases the pustule in 85% was on the head, face, or neck, and in 12% on the arm.

The infection in the trades named above is due to materials imported from Eastern countries in which anthrax is rife, *e.g.*, Van mohair, Persian wool, Siberian and Chinese horsehair, Chinese and Persian skins. Dry and dusty materials and processes are especially dangerous and greasy or moist goods (*e.g.* salted hides) less so. Where disinfection is impracticable and infected materials are used, the preventive measures turn upon suppression of dust, personal cleanliness, protective garments, and immediate attention to abrasions of the skin, however slight. Early diagnosis, prompt excision of anthrax pustules, and the use of Sclavo's serum are important.

Brass-founders' ague, attributed to zinc fumes, is characterised by recurrent attacks, with cold, hot, and sweating stages, differing from those of malaria in not being periodic.

Other provisions of the Factory Act require only brief mention here, and the following summary may suffice.

Safety.—Dangerous machinery must be fenced or made safe by position. The use of dangerous ways, works, machinery or plant, or of dangerous premises, can be forbidden by a Court. Certain dangerous employments are forbidden to "children" and "young persons," and further limitations of this kind can be imposed by the Certifying Surgeon. Where any manufacture, plant, process, or description of manual labour is certified by the Home Secretary as dangerous or injurious to health, or dangerous to life or limb, regulations (of general application) or special rules (for particular works) may be made: many such codes are in force.

Accidents which are fatal, or which prevent the injured person on any one of three following working days from doing 5 hours' ordinary work, must be registered and reported to the Factory Inspector: and also reported to the Certifying Surgeon if fatal or caused by power-machinery, or by hot liquid or molten metal, or by explosion, or by escape of gas, steam or metal. This applies also to dock processes.

Age and Sex.—Children under 12 may not be employed. Above 12 they may be employed for half-time (if they have attained a certain standard and if the local educational bye-laws permit), but must attend school for the other half. In factories they must have a certificate of fitness (as to age and physique) from the Certifying Surgeon, which may be coupled with conditions as to the nature of the employment permitted. "Young persons" are those between 14 and 18 (or between 13 and 14, subject to conditions as to educational certificates), and are eligible for full time employment, with certain limitations. Certificates of fitness are required for those under 16 employed in factories. A woman must not be employed within 4 weeks after giving birth to a child.

Hours and Intervals.—The period of employment for women and young persons in textile factories is on ordinary days 12 hours (6 to 6 or 7 to 7), less 2 hours intervals, and on Saturday 6 hours (6 to 12 or 7 to 1, with ½ hour interval, or 6 to 12.30, with an hour interval): or a weekly total of 55½ working hours. In non-textile factories and in workshops it is 12 hours on ordinary days (6 to 6, 7 to 7, or 8 to 8), with 1½ hours intervals, and on Saturdays 8 hours (6 to 2, 7 to 3, or 8 to 4), with ½ hour interval; or a weekly total of 60 hours. In laundries the period must not exceed 14 hours for women, 12 hours for young persons, or 10 hours for children in any consecutive 24 hours: nor a weekly total of 60 hours for women and young persons, and 30 hours for children. There is a further limit as to continuous spell of employment, which must not exceed 4½ hours in textile factories and printing, bleaching and dyeing works, or 5 hours in non-textile factories, workshops and laundries, without an interval of ½ hour. Certain holidays, amounting to six days in the year, are prescribed. Work on Sundays is prohibited. The hours, intervals and holidays must be fixed by notice. None of the above provisions apply to men over 18, and certain exceptions are allowed as regards women, young persons and children in special cases: *e.g.* women may be employed "overtime" for 2 hours, on not more than 3 days in any week, nor more than 30 days in any 12 months, in certain specified branches; and in others male young persons can be employed at night.

The Alkali, etc., Works Regulation Act, 1881, applies to alkali works and to the manufacture of sulphuric acid, nitric acid, chlorine, bleaching powder or liquor, sulphate or muriate of ammonia, and chemical manure, and is administered by Inspectors appointed by the **L.G.B.**

In alkali works 95 per cent. of the HCl gas evolved must be condensed, and not more than $\frac{1}{5}$ grain of HCl per cubic foot of air, smoke, or chimney gases must escape, nor more of the acid gases of sulphur and nitrogen than the equivalent of four grains of SO_3 per cubic foot. Acid drainage must not be allowed to mix with alkali waste so as to cause nuisance. The owner may require the **S.A.** to provide and maintain at his expense a drain for carrying the acid waste into the sea or any watercourse into which it can be taken without breach of the law. Alkali waste must not be deposited or discharged without the best practicable and available means being used to prevent nuisance.

Similar regulations apply to sulphuric acid works. The gases escaping must not have an acidity equivalent to more than four grains of SO_3 per cubic foot The other works scheduled also must employ the best practicable means for preventing the escape of noxious and offensive gases, and for rendering them harmless and inoffensive.

Under this Act the **L.G.B.** in 1884 prescribed special precautions against the discharge of acid and noxious fumes from salt (brine) and cement works.

An amending Act of 1892 added Venetian red works, lead deposit works, arsenic works, nitrate and chloride of iron works, muriatic acid works, fibre separation works (wherein HCl is used to separate silk or wool from cotton fibres) tar works, and zinc works, and also the *following* if H_2S be evolved, viz. alkali waste

works, barium and strontium works, antimony works, and bisulphide of carbon works.

Mines are controlled by the Coal Mines Regulation Act, 1887, and the Metalliferous Mines Regulation Act, 1872 (many of the provisions of which are extended to quarries, over 20 feet in depth, by the Quarries Act, 1894), and amending Acts. These Acts are administered by H.M. Inspectors of Mines, but in one or two minor points (see pages 483 and 488) they give powers under the Public Health Acts to the S.A.

The Shop Hours Acts, 1892, 1893, and 1895, are administered by the County and Borough Councils. They contain no sanitary provisions, but regulate the hours of employment of young persons under 18, whether wholly in a shop or partly also in a factory or workshop. The total number of hours, including meal hours, must not exceed 74 in any week, and a notice of this limit must be kept affixed in the shop. "Shops" include warehouses and licensed public houses and refreshment houses of all kinds. A further Act (Seats for Shop Assistants Act, 1899) requires one seat to be provided for every three female assistants.

The **Employment of Children Act, 1903,** enables urban S.A.'s with a population over 20,000 (or, in the case of boroughs over 10,000, and elsewhere the County Council) to make byelaws regulating the employment of children under 14 (not under the Factory or Mines Acts) and street trading by persons under 16; it forbids carrying of heavy weights or other injurious occupation, street trading by children under 11, and (in general) work between 9 p.m. and 6 a.m.; but as regards children employed in mines, factories, and workshops, these provisions are administered by Home Office Inspectors only.

Under the **Prevention of Cruelty to Children Act, 1904,** the S.A. are charged with the duty of seeing to the observance of the conditions of licences granted by a Court for the employment of children over 10 in public entertainments.

CHAPTER XX.

BYELAWS AND REGULATIONS.

Byelaws, having the force of law, may be made by Sanitary Authorities for the better government of their districts, but only in respect of certain matters, and under certain conditions, expressly stated in the Acts of Parliament. They are designed to supplement, not to summarise, vary, or supersede, the express provisions of the statute law. It is, of course, quite open to any **S.A.** to append to their byelaws a statement or summary of the requirements of the statute law bearing upon the same matters. In some cases this course is advised by the **L.G.B.** Byelaws must be reasonable, and must not in any particular be repugnant to the provisions of the general law. They have (as a rule) no force until approved by the **L.G.B.** Any byelaw may be altered or repealed by a subsequent byelaw. In framing byelaws, a **S.A.** should impose reasonable penalties, not exceeding £5 for each offence; and in the event of a continuing offence, a further penalty not exceeding £2 per day.

Urban authorities are empowered to make byelaws as follows

1. *Private scavenging.*—For imposing upon occupiers the duty of cleansing pavements and footways, of removing house refuse, and of cleansing earth-closets, ashpits, privies, and cesspools. Such byelaws are only to be made if the **S.A.** do not undertake or contract for these matters * (Public Health Act, 1875, s. 44).

2 *Prevention of nuisances*.—For the prevention of nuisances arising from snow, filth, dust, ashes, and

* But see the Public Health Acts Amendment Act, 1890, p. 300

rubbish. For the prevention of the keeping of animals on any premises so as to be injurious to health (Public Health Act, 1875, s. 44).

3. *Common lodging-houses.*—For regulating the number of lodgers and the separation of the sexes; for promoting cleanliness and ventilation; for giving notice and taking precautions in case of infectious disease; and for the general well-ordering of such houses (Public Health Act, 1875, s. 80).

4. *Houses let in lodgings.*—For regulating the number of persons and separation of the sexes in a house or part of a house let in lodgings or occupied by members of more than one family; for the registration and inspection of such houses; for drainage, privy accommodation, cleanliness and ventilation; for cleansing and whitewashing at fixed times; for paving of yards; and for giving notice and taking precautions in case of infectious disease* (Public Health Act, 1875, s. 90). The Merchant Shipping (Fishing Boats) Act of 1883 gives power to the **S.A.** to make byelaws for the regulation of *seamen's lodging houses.*

5. *Hop-pickers.*—For securing the decent lodging and accommodation of persons engaged in picking hops (Public Health Act, s. 314).

6. *Fruit-pickers.*—For securing the decent lodging and accommodation of persons engaged in picking fruit and vegetables [Public Health (Fruit-pickers) Act, 1882].

7. *Tents and vans.*—For promoting cleanliness in, and habitable condition of, tents, vans, sheds, and similar structures used for human habitation; for pre-

* The **M.O.H.** must on request inspect any house wholly let in tenements at rents not exceeding 7s. 6d. weekly, and (if satisfied) certify that the accommodation and sanitary arrangements are suitable. The effect is to exempt from Inhabited House Duty. The **S.A.** may appoint another practitioner, qualified to act as **M.O.H.**, to give such certificate (Customs and Inland Revenue Act, 1890).

venting the spread of infectious disease by the occupants thereof, and generally for the prevention of nuisances in connection with the same (Housing of the Working Classes Act, 1885).

8. *New streets and buildings.*—With respect to the level, width, construction, and sewerage of new streets; with respect to the structure of walls, foundations, roofs, and chimneys of new buildings, for securing stability and for the prevention of fires, and for purposes of health; with respect to ventilation, and sufficiency of air-space about buildings; with respect to drainage, closets, ashpits, and cesspools; with respect to the depositing of plans and sections of proposed new streets and buildings; with respect to the power of the Authority to remove, alter, or pull down any work begun or done in contravention of the byelaws; and with respect to the closure of buildings unfit for habitation * (Public Health Act, 1875, s. 157).

9. *Mortuaries.*—For the regulation of charges and management of public mortuaries (s. 141).

10. *Cemeteries.*—For the regulation of charges and management [Public Health (Interments) Act, 1879].

11. *Slaughter-houses.*—For the licensing, registering, and inspection of slaughter-houses and knackers' yards, for preventing cruelty therein; for cleanliness and daily removal of filth; and for providing a supply of water (Public Health Act, 1875, s. 169).

12. *Offensive trades.*—For preventing or diminishing the noxious or injurious effects of any offensive trades (Public Health Act, 1875, s. 113).

13. *Markets and fairs.*—For preventing nuisances in markets and fairs; for inspection of slaughter-houses, and daily removal of refuse therefrom, for preventing the sale or exposure for sale of unwholesome provisions; and for many other purposes (Public Health Act, 1875, s. 167).

* For further powers, see page 501.

14. *Open spaces.*—For the regulation of public walks and pleasure grounds (Public Health Act, s. 164). For the regulation of any open space, churchyard, cemetery, or burial ground over which the **S.A.** has control (Open Spaces Act, 1887).

15. The Municipal Corporations Act, 1882, s. 23, gives power to the Council of a borough to make byelaws for the prevention and suppression of *nuisances* not already punishable in a summary manner by virtue of any Act in force throughout the borough. County Councils have similar power under the 16th section of the Local Government Act, 1888.

16. For the regulation of *buildings provided under the Housing of the Working Classes Acts.*

17. By adopting certain portions of the Public Health Acts Amendment Act, the **S.A.** may make byelaws as to *public conveniences* provided by them; and also additional byelaws as to *new (and old) buildings, removal of house-refuse, and prevention of nuisances* (page 501).

18. For *means of escape from fire* in factories and workshops (Factory and Workshop Act, 1901, s. 15).

Rural Authorities have similar powers in respect of the following:—

Private Scavenging (1, 17).
Common Lodging-houses (3).
Houses let in Lodgings, and Seamen's Lodging-houses (4).
Hop-pickers (5).
Fruit-pickers (6).
Tents and Vans (7).
Mortuaries (9).
Means of escape from fire in factories and workshops (18).

And also under the Housing of the Working Classes Acts (16). By adopting portions of the Public Health Acts Amendment Act, they can make certain byelaws as to new (and old) buildings (8, 17). The **L.G.B.** may confer upon them any other powers as to byelaws which the Public Health Acts give to Urban Authorities (Public Health Act, 1875, s. 276).

Byelaws as to common lodging-houses must be made by every **S.A.**, and as to slaughter-houses by every urban **S.A.**; the rest are optional.

Any **S.A.** may make regulations under the Dairies Order (see p. 534).

A **S.A.** may make regulations (to be approved by the **L.G.B.**) for the removal to hospital, and detention in hospital as long as necessary, of persons brought within their district by ship or boat, and infected with any dangerous infectious disorder (Public Health Act, s. 125). They may also make regulations for the management of places provided by them for post-mortem examinations ordered by a coroner.

Model Byelaws have been prepared by the **L.G.B.** in respect of certain of the matters upon which **S.A.** have power to frame byelaws. The following have been issued up to the present time:—

Private Scavenging.	Pleasure Grounds.
Prevention of Nuisances.	Horses, etc., let for Hire.
Common Lodging-houses.	Pleasure-boats.
New Streets and Buildings.	Houses let in Lodgings.
Markets.	Cemeteries.
Slaughter-houses.	Mortuaries.
Hackney-carriages.	Offensive Trades.
Public Bathing.	Hop-pickers.
Baths and Wash-houses.	

These Models* are now very generally adopted, with occasional slight modifications, by **S.A.** seeking to frame byelaws. The following summary includes only those which have a more direct bearing upon sanitary matters:—

1. Private Scavenging.†—The occupier of any premises must cleanse the footways and pavements

* The semi-official *Annotated Model Byelaws* (Knight and Co.) contains many important notes, additions, and illustrations.

† Applicable to districts where the **S.A.** do not undertake these duties.

adjoining his premises *daily* except Sunday. He must remove the house-refuse *once a week*, and excreta at intervals not exceeding the following maximum limits :—

	Must be cleansed at least—
Earth-closets, with fixed receptacle .	once in three months
,, ,, movable ,, .	once a week.
Privies, whether the receptacles are fixed or movable	once a week.
Ashpits, whether receiving excreta or not	once a week.
Cesspools	once in three months.

2. Prevention of Nuisances.

(*a*) *Clearing away snow.*—The occupier of any premises must clear away snow from the footways and pavements adjoining his premises, as soon as possible after it ceases to fall.

(*b*) *Scavenging.*—The refuse from any premises shall only be removed in a suitable covered receptacle or carriage ; and if from premises within 20 yards of any dwelling, public building, or place of business only between [7.0 and 9.30 a.m.] from November to February, and between [6.0 and 8.30 a.m.] from March to October. Refuse must not be deposited upon any road, and any refuse accidentally falling upon a road must be immediately gathered up and the place cleansed.

(*c*) *Deposit of nightsoil and other refuse.*—No load of filth must be deposited for more than [24] hours within [100] yards of any street, dwelling, public building, or place of business. Nightsoil deposited for agricultural purposes upon land within [100] yards of a street, dwelling, etc., and not deodorised, must at once be dug or ploughed into the ground.

(*d*) *Keeping of animals.*—Swine must not be kept within [100] feet of any dwelling, nor cattle where they may pollute water likely to be used for drinking, domestic, or dairy purposes, or for

manufacturing drinks. The same prohibitions apply to storage of dung. Premises wherein are kept any swine, cattle, horses, etc., must be provided with proper receptacles for manure, and with efficient drainage; the receptacle must be watertight, covered, and entirely above the level of the ground, and it must be cleansed at least once a week; the drain must be properly constructed and kept in order at all times, so as to convey all liquid filth to a sewer, cesspool, or other suitable receptacle.

3. Common Lodging-houses.

(*a*) *Number of lodgers.*—The **S.A.** may specify by notice in writing the maximum number of lodgers to be accommodated in each room, and the keeper must not allow this number to be exceeded; notice stating the maximum number allowed must be exhibited in each room.* The **S.A.** may vary the number from time to time by further notice.

(*b*) *Separation of sexes.* In general no person above ten years of age must occupy the same sleeping-room as persons of the opposite sex, but rooms may be set apart for the sole use of married couples, to the exclusion of other persons over ten years of age, on condition that every bed is screened off. No bed must be occupied by more than one male above ten years of age.

(*c*) *Cleanliness of premises.*—The yards, etc., must be kept clean and in good order; all floors swept daily and washed once a week; all windows, painted surfaces, and fittings of wood, stone, or metal, kept clean.

(*d*) *Closets* must be kept clean and in good and efficient order.

(*e*) *Ashpits* must be kept clean and in good order. No filth or wet refuse must be thrown into ashpits designed for dry refuse only.

* It is usual to require at least 300 cubic feet of air-space per head, but to count two children as one adult.

(*f*) *Management of sleeping-rooms.*—The windows must be opened fully for an hour in the morning, and an hour in the afternoon, except in case of stress of weather or occupation of the room by a sick person, or other sufficient cause. Beds must be stripped of clothes and exposed freely to the air for an hour each day, and must not be reoccupied within eight hours after being vacated. All refuse and slops must be removed every day before 10 a.m., and all utensils cleansed daily. Every sleeping-room must be provided with sufficient bedsteads, beds, bedclothes, and utensils, for the use of the maximum number of lodgers to be received therein.

(*g*) *Facilities for washing.*—A sufficient supply of suitable basins, water, and towels must be provided for the use of lodgers; and must be kept clean and renewed as required.

(*h*) *Precautions in respect of infectious diseases.*—If the keeper finds that any lodger is suffering from an infectious disease, he must at once take all necessary precautions. No person, except a relative or attendant, must occupy the same room as the sick person. If the patient is removed to hospital by the **S.A.** the keeper must afford all facilities for removal and must adopt all precautions directed by the **M.O.H.**

He must, if required by the **M.O.H.** to do so, temporarily cease to receive lodgers into any infected room. At the end of the case by removal, recovery, or death, the keeper must at once give notice to the **M.O.H.** and must cleanse and disinfect every part of the infected rooms and their contents, and in doing so must comply with all instructions of the **M.O.H.** When the cleansing and disinfection are completed, he must give notice thereof to the **M.O.H.**, and must not receive any lodger into the rooms in question until two days after such notice has been given.

(*i*) *A copy of the byelaws* in force with respect to Common Lodging-Houses, supplied by the **S.A.,** must be exhibited in some conspicuous place in the house, and must not be concealed, altered, obliterated or injured.

As some of the most important regulations regarding common lodging-houses are contained in the Public Health Act, and are, therefore, omitted in the byelaws, it is desirable that a statement of the provisions of sections 75 to 89 of the Public Health Act should accompany the copy of byelaws supplied to each common lodging-house.

As regards the question of the suitability of any particular premises or particular rooms for registration, a memorandum, issued by the **L.G.B.,** points out that a common lodging house should, in the first place, possess the conditions of wholesomeness needed for houses in general, and secondly, that it should have arrangements fitting it for the special purpose of receiving a given number of lodgers. Inside walls should not be papered. Every registered room should have special means of ventilation (by chimney if possible), and a window opening freely and directly upon the outer air. There should be kitchen and day-room accommodation apart from the bedrooms. Rooms partially underground should not be registered as sleeping rooms. There should be a supply of pure water allowing at least ten gallons per head per day for the maximum number of inmates, and one closet for every twenty registered lodgers. Wherever practicable, there should be a separate place for washing, not in the bedrooms, with fixed basins and trapped and disconnected waste-pipes.

4. New Streets and Buildings.

(*a*) *Streets.* No new street must be less than 36 feet wide, if it exceeds 100 feet in length or is intended to be a carriage road; nor less than 24

feet in any case. One end at least must be quite open.

(*b*) *Sites.*—No buildings must be erected upon soil polluted with animal or vegetable matter. Sites in low and damp situations, near rivers or in excavations, must be elevated artificially. The site of a new house must be entirely asphalted or covered with 6 inches of concrete.

(*c*) *Walls* of all new buildings must be constructed of good bricks, stone, or other hard and incombustible materials, properly bonded and solidly put together with good mortar compounded of good lime and clean sharp sand or other suitable material, or with good cement, or with good cement mixed with clean sharp sand. Every wall must have a proper damp course of durable and impervious material beneath the level of the lowest timbers and at least 6 inches above the ground. If the ground is to be in contact with a wall above the level of the floor of the lowest storey, that wall must be made double, with a cavity $2\frac{1}{2}$ inches wide extending from the base of the wall to 6 inches above the surface of the adjoining ground; and damp courses must be inserted both at the base of the wall and at the level of the top of the cavity. Walls of new houses must be at least 9 inches thick, increasing according to a prescribed scale when the height is greater than 25 feet, or the length greater than 30 feet. Party-walls must be carried up at least 15 inches above the roof, the distance to be measured at right angles to the slope of the roof. The **L.G.B.** permit certain modifications in the byelaws for buildings in rural districts.

(*d*) *Roofs* must be made of incombustible materials, and provided with gutters leading to rain-pipes.

(*e*) *Open space.*—A new house must have along its whole frontage an open space measuring at least 24 feet to the boundary of any land or premises

immediately opposite or to the opposite side of the street. In the rear there must be an open space exclusively belonging to the house, at least 150 square feet in area, and free from any erection above the ground level except a closet and an ashpit; the open space must extend along the entire width of the house, and must measure in no case less than 10 feet from every part of the back wall of the house; if the house is 15 feet high, the distance must be 15 feet; if 25 feet, then 20 feet, and if 35 feet or more, then 25 feet at least.

(*f*) *Ventilation beneath floors.*—If the floor of the lowest storey is boarded, there must be a clear space of at least 3 inches between the boards and the impervious covering of the site, and the space must be ventilated.

(*g*) *Windows* opening directly into the external air must be provided in every habitable room. The window area must be at least one-tenth of the floor area; at least half of each window must be made to open, and it must open at the top.

(*h*) *Ventilation.* Every habitable room must either have a fireplace and chimney, or a special ventilating aperture or air-shaft with an unobstructed sectional area of at least 100 square inches. Every new building must be provided with adequate means of ventilation.*

(*i*) *Drainage.*—Damp sites must be drained by earthenware field pipes properly laid to a suitable outfall, but not directly communicating with any sewer or cesspool or drain containing sewage. Rain-pipes must be provided to carry away all water falling on the roof without causing dampness of the walls or foundations. The level of the lowest storey must be such as to allow of the construction of a drain sufficient

* The semi-official Model Byelaws under the Public Health Acts Amendment Act prescribe a minimum height of 9 feet in every part, except in attics used as bedrooms, when a minimum height of 5 feet is permitted, *if in two-thirds of the area the height is not less than 9 feet.*

for the drainage of the building communicating with a sewer at a point above the centre of the sewer. All drains for sewage must be made of impervious pipes 4 inches or more in internal diameter, laid with a proper fall in a bed of concrete, and with watertight joints. Every drain inlet not intended for ventilation must be trapped. No drain conveying sewage must pass under a building unless no other mode of construction is practicable; in that case it must be laid in a direct line for the whole distance beneath the house, and must be embedded in and covered with concrete 6 inches thick all round, and must be laid at a depth below the surface at least equal to its diameter, and, lastly, must be ventilated at each end of the portion beneath the building. The main drain must be trapped at a point within the curtilage, but as distant as practicable from the building. Branch drains must join other drains obliquely in the direction of flow.

(*j*) *Ventilation of drains.*—There must be at least two untrapped ventilating openings into the drains, according to one of the following alternative arrangements:—(1) One opening consists of a shaft or disconnecting chamber opening at or near the ground level, and situated as close as possible to the trap specified above, but on the house side of it; the other opening is a pipe or shaft carried from a point as far distant as possible from the said trap (*i.e.* as near as possible to the head of the drain) vertically upwards in such manner and to such height (in no case less than 10 feet) as to prevent any escape of foul air into any building; but (2) if more convenient, the relative positions of these openings may be reversed, the shaft being placed near the trap, and the opening at the ground level at the head of the drain. The ground-level opening must have a grating, with apertures equal in total area to the sectional area of the drain.

The pipe or shaft at the other end of the drain (whether used as a soil pipe or not) is required to have a sectional area equal to that of the drain, and in no case less than 4 inches; and bends and angles are to be avoided as far as practicable.

(*k*) *Disconnection of drains from house.* — No drain inlet is permitted within a building except the inlet necessary for a water-closet. Every soil pipe must be at least 4 inches in diameter, must be placed outside the building, and must be continued upwards in full diameter without bends or angles (except where unavoidable), to such a height and such a point as to afford a safe outlet for sewer air. There must be no trap between the soil pipe and the drain to which it leads, nor in any part of the soil pipe except such as may be necessary in the construction of the water-closet. The waste pipe from a slop sink must conform to the same requirements as a soil pipe. The waste pipes from any other sink, bath or lavatory, the overflow pipe from any cistern and from any "safe" under a bath or water-closet, and every pipe for conveying waste water, must be taken through an external wall and must discharge in the open air over a channel leading to a trapped gulley grating at least 18 inches distant.

(*l*) *Water-closets* must have a window opening directly into the external air, and measuring 2 feet by 1 foot clear of the frame; and, in addition to the window, adequate means of constant ventilation by air bricks, air shafts, etc. Such closets, if within the building, must adjoin an external wall. The water must be supplied to a water-closet by means of a special cistern. The apparatus must be suitable for effectual flushing and cleansing of the basin; the basin must be made of non absorbent material, and of such shape and capacity as to receive and contain a sufficient quantity of water, and to allow all filth to

fall free of the sides directly into the water. "Containers" and "D-traps" are forbidden.

(*m*) *Earth-closets* are subject to the same conditions as water-closets so far as regards position, lighting, and ventilation. Proper arrangements must be made for the supply of dry earth, and its effectual and frequent application to the excreta; also for convenience of scavenging, and for exclusion of rainfall and drainage. The receptacle for excreta, whether fixed or movable, must be so constructed as to prevent absorption or escape of the contents, and to exclude rainfall and drainage; if fixed, its capacity must not be greater than may suffice for (*three months ?*) nor in any case greater than (*forty ?*) cubic feet, and it must in every part be (*three ?*) inches above the ground. (The maximum limit of size may with advantage be reduced to *two* cubic feet in the case of earth-closets placed inside houses.)

(*n*) *Privies* must not be erected within 6 feet of a dwelling, public building, or place of business, nor within (*fifty ?*) feet of any water likely to be used for drinking, or domestic purposes; or for manufacturing drinks, nor otherwise in such a position as to entail danger of the pollution of such water. Privies must be built so as to admit of convenient scavenging, without carrying the contents through any dwelling, public building, or place of business. There must be an opening for ventilation at the top; the floor must be paved, and raised 6 inches above the ground in all parts, with a fall of half an inch per foot towards the door. The receptacle may be fixed or movable. If movable, as in pail-closets, the floor of the area beneath the seat must be flagged or asphalted, and raised 3 inches above the ground level, and all the sides of the said area must be made of flag, slate, or brick, at least 9 inches thick, and rendered in cement. If the receptacle is fixed, it must be in every part

3 inches above the ground level, and its capacity must not exceed 8 cubic feet;* means must be provided for the application of ashes and dry refuse to the excreta, and for the exclusion of rainfall and drainage, and for convenient access for scavenging; the materials and construction must be such as to prevent absorption or leakage, and there must be no connection with any drain.

(*o*) *Ashpits* must not be constructed within 6 feet of any dwelling, public building, or place of business, nor within (50 ?) feet of any water likely to be used for drinking or domestic purposes, etc., nor otherwise in such a position as to entail danger of the pollution of such water. Ashpits must be so placed and constructed as conveniently to allow of scavenging without carrying the contents through any dwelling, public building, or place of business. The capacity must not exceed 6 cubic feet or such less capacity as may suffice for a period not exceeding one week. The walls must be of flag, slate, or brick, at least 9 inches thick, and rendered inside with cement; the floor must be flagged or asphalted, and raised at least 3 inches above the ground level. The ashpit must be roofed and ventilated, and provided with a door so arranged as to allow of convenient removal of the contents, and to allow also of being closed and fastened. The ashpit must not be connected with any drain.

(*p*) *Cesspools* must not be constructed within (50 ?) feet of any dwelling, public building, or place of business, nor within (100 ?) feet of any water likely to be used for drinking, or domestic purposes, or for manufacturing drinks, or otherwise in such a position as to entail danger of pollution of such water. Cesspools must be so constructed and placed as con-

* These dimensions are based upon the assumption of weekly scavenging.

veniently to admit of scavenging and cleansing without carrying the contents through any dwelling, public building, or place of business. They must not be connected with any sewer. They must be covered over by an arch or otherwise, and adequately ventilated; and must be constructed of brick in cement, rendered inside with cement, and with a backing of at least 9 inches of clay.

(*q*) *Closure of premises unfit for occupation.*—The **S.A.** may under certificate from the **M.O.H.** or Surveyor, declare any building or part of a building erected after ...... unfit for habitation, and order it to be closed until rendered fit for habitation. Opportunity must be given to the owner to show cause why such order should not be made.

(*r*) *Plans and sections* must be submitted, showing in detail the construction of all proposed new streets or buildings. (The Public Health Act, s. 158, requires that the **S.A.** shall signify their approval or disapproval of the plans within a month after receiving them.)

(*s*) *Inspection.*—Notice must be given to the Surveyor of the dates upon which work is to be commenced, and upon which any sewer, drain, or foundation is to be covered up; notice must also be given of the completion of the work. Free access for inspection must be afforded to him at all times during the progress of the work.

(*t*) *Demolition of illicit works.*—If any work to which the byelaws apply is done in contravention of such byelaws, the **S.A.** are empowered to remove, alter, or pull down such work.*

* The Model Byelaws contain no provision for the sewerage of new streets, owing to the wide variation in the conditions in different localities. "*It may be doubted whether any powers, which under such bye-laws may be lawfully assumed by Sanitary Authorities, will, as regards extent and efficacy, compare with the powers which they derive from the express provisions of the Public Health Act.*"—**L.G.B.** Circular to Urban **S.A.**

5. Slaughter-houses.

(*a*) *Licences.*—Applications for licence of existing premises, or erection of new slaughter-houses, must be made upon a specified form, and must include full particulars as to the position, form, area, cubic space, etc., of the buildings and appendages; materials and construction of walls and floors; means of water supply, drainage, lighting, and ventilation; means of access for cattle; number, position, and size of stalls or lairs, and number of animals to be accommodated therein, distinguishing oxen, calves, sheep, and swine. The boundaries must also be shown, and, in the case of old premises, particulars as to the ownership and the applicant's tenure must be given.

(*b*) *Registration.* If the **S.A.** approve the application, a licence shall be issued to the applicant, and must be registered by him at the office of the **S.A.**

(*c*) *Inspection.* Free access to every slaughter-house for the purpose of inspection must be afforded at all reasonable times to the **M.O.H.** Inspector, Surveyor, and Committees appointed by the **S.A.**

(*d*) *Water* must be supplied to every animal kept in a lair prior to slaughter.

(*e*) *Mode of slaughter.*—Cattle must be secured by the head so as to be felled with as little pain as practicable.

(*f*) *Drainage, water supply, and ventilation* must be kept in efficient order.

(*g*) *Cleanliness.*—The walls and floor must be kept in good order and repair, and must be thoroughly cleansed within three hours after any slaughtering; the walls and ceiling must be limewashed within the first ten days of March, June, September, and December respectively.

(*h*) *Animals not to be kept.*—No dog may be kept in a slaughter-house; nor other animal, unless intended for slaughter upon the premises, and then only

in proper lairs, and not longer than may be necessary for preparing it for slaughter by fasting or otherwise.

(*i*) *Removal of refuse.*—Suitable vessels made of non-absorbent materials, and provided with close-fitting covers, must be provided for the reception of blood, manure, garbage, and other refuse; all such matters must be placed in these vessels immediately after the slaughtering; the refuse must be removed within 24 hours, and the vessels forthwith cleansed. All skins, fat, and offal must be removed within 24 hours.

"The Board have considered that the statutory terms do not warrant........ regulations directly affecting the structure of the premises. But......in the exercise of the discretionary power of licensing which has been conferred upon the **S.A.**, the following rules as to site and structure should influence their decision upon each application for a licence:—

"1. The premises ...... should not be within 100 feet of any dwelling-house; and the site should be such as to admit of free ventilation by direct communication with the external air on two sides at least of the slaughter-house.

"2. Lairs for cattle in connection with the slaughter-house should not be within 100 feet of a dwelling-house.

"3. The slaughter-house should not in any part be below the surface of the ground.

"4. The approach to the slaughter-house should not be on an incline of more than one in four, and should not be through any dwelling-house or shop.

"5. No room or loft should be constructed over the slaughter-house.

"6. The slaughter-house should be provided with an adequate tank or other proper receptacle for water, so placed that the bottom shall not be less than six feet above the level of the floor of the slaughter-house.

"7. The slaughter-house shall be provided with means of thorough ventilation.

"8. The slaughter-house should be well paved with asphalte or concrete, and laid with proper slope and channel towards a gulley, which should be properly trapped and covered with a *grating*, the bars of which should not be more than three-*eighths* of an inch apart. Provision for the effectual drainage of the slaughter-house should also be made.

"9. The surface of the walls in the interior of the slaughter-house should be covered with hard, smooth, impervious material to a sufficient height.

"10 No water-closet, privy, or cesspool should be constructed within the slaughter-house. There should be no direct communication between the slaughter-house and any stable, water-closet, privy, or cesspool.

"11 Every lair for cattle in connection with the slaughter-house should be properly paved, drained and ventilated

"No habitable room should be constructed over any lair."
—**L G B**, *Memorandum.*

6. Houses let in lodgings (or "tenements") —(*a*) *Definitions.* A "lodging-house" is defined as a house or part of a house let in lodgings, or occupied by members of more than one family. The "landlord" is the person letting such lodging house, or entitled to receive the profits of such letting; and a "lodger" is a person to whom any room or rooms in such house, or part of a house, have been let for his use and occupation. (*b*) *Limitation as to class.*—(1) On a rent limit, say of 3s. to 8s. if unfurnished, or 5s. to 10s. if furnished; or (2) where the landlord resides on the premises, and the letting is to not more than one lodger. (*c*) *Cubic space.* A room used exclusively as a sleeping-apartment shall not be so used at any one time by a greater number of persons than will admit of the provision of 300 cubic feet of air space for each person over ten years of age, and 150 cubic feet for each person under ten years. A room not exclusively used as a sleeping-room shall not be used at any one time by a greater number of persons than will admit of the provision of 400 cubic feet of air-space for each person over ten years of age, and 200 cubic feet for each person under ten years. (*d*) *Landlord to furnish returns.*—The landlord shall, if required by the **S.A.**, furnish the following particulars:—(1) Number of rooms in the house; (2) number of rooms let in lodg-

ings or occupied by members of more than one family; (3) the manner of use of each room; (4) the number, age, and sex of the occupants of each room used for sleeping; (5) full name of the lessee of each room; (6) the rent payable by each lessee. (*e*) *Inspection.*—Facilities for inspection shall be afforded to the **M.O.H.**, Inspector, or Surveyor at all times by the landlord and lodgers. (*f*) *Closet accommodation.*—The landlord shall provide sufficient closet accommodation, in the proportion of at least one closet for every twelve persons of the maximum number of lodgers allowed by the byelaws, and maintain the closets and all necessary appurtenances in efficient order. All closets must be kept clean, and supplied with dry earth (if earth-closets) or water (if water-closets) as required.* (*g*) *Ashpits* must be maintained in repair by the landlord, and must be kept clean; no filth or wet refuse must be thrown into an ashpit designed for dry refuse only. (*h*) *Cleanliness of rooms.*—The floors of all rooms must be swept daily, and washed every week. All windows, all wood, stone, or metal fixtures, and all painted surfaces must be kept clean. All solid or liquid filth or refuse must be removed from every room every day, and all receptacles thereof cleansed. (*i*) *Keeping of animals.*—No animal must be kept upon the premises in such manner as to render the premises filthy. (*j*) *Water storage.*—All cisterns for storing water must be kept clean. (*k*) *Ventilation.*—The landlord must maintain in efficient order the means of ventilation of all parts of the house. (*l*) *Annual cleansing of premises.*—Every year, in the first week of the month of ...... the landlord must cleanse every part of the premises, and whitewash the ceilings and walls throughout the

* If the byelaws respecting new streets and buildings are not in force in the district, those of them which refer to the construction of closets may be introduced here.

house, except surfaces to which limewashing may be unsuitable, and these must be cleansed and, if necessary, painted. (*m*) *Yard and open spaces.*—The yard and all open spaces must be kept clean and in good order. The yard must have a hard, impervious pavement laid upon concrete, and sloped to a channel leading to a trapped gulley grating; all these must be kept in repair by the landlord. (*n*) *Ventilation of sleeping-rooms.*—The window of every sleeping-room shall be kept open for an hour in the forenoon and an hour in the afternoon, except in case of stress of weather, or occupation of the room by a sick person, or other sufficient reason. (*o*) *Infectious diseases.*—The landlord must immediately give written notice to the **M.O.H.** if he learns that any person in the house is ill of an infectious disease. A lodger must immediately give written notice to the **M.O.H.**, and verbal or written notice to every lodger in the house, if he has reason to believe that any occupant of any room is ill of an infectious disease. Where a justice's order has been obtained for the removal to a hospital of a person suffering from any dangerous infectious disease, both the landlord and the lodger in whose tenement such sick person is shall take such steps as may be requisite on their respective parts for the safe and prompt removal of such person, and shall adopt all such precautions as may be most suitable, in accordance with any instructions of the **M.O.H.**

Where a duty imposed upon or a prohibition applied to the landlord of a lodging house is by any byelaw expressly imposed or applied subject to the provisions of these byelaws, proceedings shall not be taken against him for an offence against the byelaw unless and until the landlord, after service upon him of a notice in writing from the Council, signed by the **M.O.H.**, or clerk of the authority, requiring him within a reasonable time specified in the notice to

comply with the byelaw, has failed to comply with the byelaw within that time.

The landlord is made responsible for the structural repair of every part of the premises, for the efficiency of the closets and of the means of ventilation, for the annual cleansing, and for the detailed cleansing of all parts (including yards, closets, staircases, and passages) which are not let for the sole use of one tenant. The tenant is responsible for the cleanliness and management of the rooms rented by him, and of all other parts of the premises of which he has the sole use.

7. Cemeteries.—(*a*) *Definitions.*—A "grave" is defined as a burial-place formed in the ground by excavation, and without any internal wall of brick-work or stonework, or any other artificial lining. A "vault" is an underground burial-place of any other construction. (*b*) *Vaults.*—Every vault shall be enclosed with walls of brick or stone, solidly put together with good mortar or cement. (*c*) *Common graves.*—Not more than one body shall be buried at any one time in a grave in respect of which no exclusive right of burial has been granted. (Exception is made in the case of two or more members of the same family.) Such a grave shall not be reopened for the purpose of a further burial within eight years after the burial of a person aged less than twelve years, nor within fourteen years after the burial of a person aged more than twelve years. (Exception is made in the case of members of the same family.) (*d*) *Minimum covering of earth.*—No part of a coffin shall be buried at a less depth than three feet below the ground adjoining the grave, if it contains the body of a person aged less than twelve years; nor at a less depth than four feet if the age of the deceased was over twelve years. A layer of earth, not less than one foot in thickness, shall be interposed between every coffin and the coffin nearest to it. (*e*) *Closure of vaults.*—A coffin buried

in a vault shall, within twenty-four hours after burial, be wholly and permanently embedded in and covered with good cement concrete, not less in any part than 6 inches in thickness; or wholly and permanently enclosed in a separate cell, constructed of slate or flag, not less than two inches thick, and jointed in cement, or of brick in cement, and in such manner as to prevent as far as practicable the escape of noxious gas.

8. Mortuaries.—The only provisions of sanitary importance suggested in this series are the following: A body deposited in the mortuary shall be removed therefrom for interment within ..... days after death; but if the deceased has died of an infectious disease, the body shall be removed for interment within...........days after death.

An **L.G.B.** memorandum makes the following general suggestions in regard to construction and management:

The buildings should be isolated and unobtrusive, but substantial, structures of brick or stone. Every chamber for the reception of corpses should be on the ground floor. In addition to such chamber there should be a waiting room, a caretaker's house, and a shed or outhouse. Every mortuary chamber should be lofty, and there should be a ceiling or a double roof, with an intervening space of eight inches, for the sake of coolness. The area should be sufficient to allow freedom of movement between the slabs. The windows should be on the north side, if practicable; if otherwise, they should have external louvre blinds. Louvres, or air gratings, under the eaves will be the best means of ventilation. The pavement must be even and close, and a cement floor is preferable. The slabs should be of slate, and $2\frac{1}{2}$ ft. to 3 ft. from the floor. Water should be laid on within the chamber. The walls and ceiling should be whitewashed,

Inspector of Nuisances, Surveyor, or any committee specially appointed by the **S.A.** on that behalf.

10. Hop-pickers.—(*a*) *Application.*—These byelaws apply to all tents, sheds, barns, or other places occupied as temporary dwellings by hop-pickers, but not to places inhabited throughout the year. (*b*) *Habitable condition.*—Such temporary habitations are required to be clean, dry, weatherproof, and to be ventilated and lighted. (*c*) *Closet accommodation.*—There must be adequate privy accommodation for the separate use of each sex. (*d*) *Water.*—There must be a sufficient supply of good water for drinking, cooking, and washing. (*e*) *Cooking.*—There must be a separate cooking-place for every fifteen persons authorised to be received. (*f*) *Area.*—An average floor space of 15 square feet must be allowed for each occupant, but two children under ten years of age may be counted as one adult. (*g*) *Bedding.*—Clean straw or other suitable material must be supplied for bedding, and renewed as required. The beds must be screened off in places occupied by adults of different sexes. (*h*) *Cleansing.*—The premises and appointments must be thoroughly cleansed immediately before occupation, the internal surfaces limewashed, and all offensive accumulations cleared away. The cleansing must be repeated as required from time to time during the period of occupation.

(Similar byelaws may be made in respect of the accommodation of persons engaged in picking fruit or vegetables.)

CHAPTER XXI.

VITAL STATISTICS.

Population.—A census has been taken decennially since 1801, and gives detailed information regarding each county, union, registration district and sub-district, and urban district. The chief data are the total number of inhabitants in each area, the numbers living of each sex and at certain age-periods, and the numbers employed in certain callings.

The official estimate of population for any year is made by assuming that increase or decrease has gone on since the last census at exactly the same rate as between that and the previous census. This assumption is arbitrary, and seldom accords with the facts as ascertained by the next census.

If a population of 100,000 in a given year becomes 101,000 in the next year, the estimate for the third year is 102,010, not 102,000.

If $p =$ the population in any given year, and $r =$ the factor of annual increase (in the above example $r = 1{\cdot}01$), then in one year the population will become $p \times r$, in two years $p \times r^2$, and in n years $p \times r^n$.

The census is taken, not at the middle of the year, but at the end of the first quarter. Given a census population of x in 1891, and y in 1901, the rate of *decennial* increase is $\frac{y}{x}$, that of *annual* increase $\sqrt[10]{\frac{y}{x}}$, and that of *quarterly* increase $\sqrt[40]{\frac{y}{x}}$. Hence—

$$\log. y - \log. x = \log. \text{ rate of decennial increase,}$$

$$\text{and } \frac{\log. y - \log. x}{10} = \log. \text{ rate of annual increase,}$$

$$\text{and } \frac{\log. y - \log. x}{10 \times 4} = \log. \text{ rate of quarterly increase.}$$

Thus the logarithm of the estimated mid-year population for 1901 is, $\log. y + \frac{\log. y - \log. x}{10 \times 4}$; and for 1908,

$$\log. y + \frac{\log. y - \log. x}{10 \times 4} + 7\,\frac{\log. y - \log. x}{10}.$$

The following calculation of the mid-year 1905 population from census data of 1891 and 1901 may serve as an example :—

(*a*) The census population of 1901 was 100,970; log. 100,970 =	5·0041924
(*b*) The census population of 1891 was 87,842; log. 87,842 =	4·9437022
(*c*) By subtraction, the logarithm of *decennial* increase was, therefore	0·0604902
(*d*) Dividing by 10, the log. of *annual* increase is obtained . . . . . =	0·0060490
(*e*) Again dividing by 4, the log. of *quarterly* increase is obtained . . . . =	0·0015122
(*f*) Adding together log. 1901 census population (*a*), and log. quarterly increase (*b*), and four times log. annual increase (*d*), we get the log of 1905 mid-year population . =	5·0299017

And on referring to the tables, the number corresponding to this logarithm is found to be 107,128.

There are obvious limitations to the value of such an estimate. The rate of increase is not the same in the centre of a town as in the growing suburbs. New houses are springing up and becoming inhabited in the latter, apart from the "natural increase" by excess of births over deaths; while in the former there may even be an actual decrease of population, owing to the displacement of dwellings by business premises.

If the estimate is very wide of the mark, some indication of this may be given by an apparently excessively high or low birth-rate and death-rate; by the number of inhabited houses,* as ascertained from the rate-books or other sources; by returns

* The average number of persons per inhabited house is fairly constant for each locality, though varying considerably in different towns, according to the proportion of "tenement houses," and houses occupied by one family.

of those who by migration have evaded vaccination; by returns of school attendance, or by inference from the condition of the local industries. In villages, where the local conditions are well known, a better estimate can sometimes be made from such data than from calculations based upon a remote census.

The actual increase is dependent upon the balance between births and immigration on the one hand, and deaths and emigration on the other. The excess of births over deaths is termed the "natural increase." As regards towns, the *actual* is, upon the average, greater than the *natural* increase, since there is a tendency to migration from rural to urban districts. In times of depression of local trade there is emigration to other districts; whereas, when trade is flourishing, labour is attracted from rural districts and from other towns.

The *age-distribution* of a population is ascertained by each census, and may be assumed to remain constant until the next census; that is, the rate of increase is assumed to be uniform at all ages. There are, however, very material differences among towns, and between town and country, in this respect, and as the tendency to death is much greater among the very young and very old, it becomes important to allow for these variations in drawing inferences from death-rates as to the health conditions of a community. Owing to the immigration of young adults from rural districts, town populations almost always contain a larger proportion of persons between 15 and 45 than is found in the country at large; and hence a higher birth rate and (under equal health conditions) a lower death rate are to be expected *a priori*.

Births must, according to the Births and Deaths Registration Act of 1874, be registered within 42 days.

More males than females are born, in the proportion of nearly 104 to 100, but this excess is diminishing. Owing to the higher death-rate among males, the survivors of the two sexes are nearly equal in number at the end of the first year of life, and thenceforward the females are in the majority. Illegitimate births form less than 5 per cent. of the total.

Still-births, which Farr estimated at 4 per cent. of the total births, are not included in the returns.

The *Birth-rate* is the proportion of births in one year per 1,000 persons living; that is—

$$\frac{\text{No. of births in the year}}{\text{mid-year population}} \times 1{,}000.$$

For shorter periods, such as quarters or weeks, the rate is calculated on the assumption that the like periods throughout the year would yield the same proportion: so that the birth-rate during $\frac{1}{x}$th part of a year is—

$$\frac{\text{No. of births during the period in question}}{\text{mid-year population}} \times x \times 1{,}000.$$

For ordinary purposes it is sufficient to regard the year as consisting of 365 days, or 52 weeks; but if greater precision is required, the astronomical year may be used—namely, 365·24 days, or 52·177 weeks.

The English birth-rate, which was 35·4 in 1871–80, declined to 28·4 in 1903. It is higher in towns, and in times of prosperity; lower in rural districts, and in times of depression of trade.

A sounder basis of population for the purpose is that of women at ages 15-45; or, still better, married women at those ages (with exclusion of illegitimate births, the proportion of which is variable and decreasing, and averages about 4 per cent. of the total). On this latter basis the rate per 1,000 was 293 in 1870-2, 286 in 1880-2, 264 in 1890-2, and 236 in 1900-2. Even this fails to take account of material differences in fertility at the several ages within the limits stated.

Deaths must be registered within five days.

Death-rates are calculated in the same way as birth-rates, but certain corrections may be applied.

Correction for non-residents.—The deaths of strangers who happen to die in the district should be excluded. Without this correction the true rate may be seriously overstated if the district contains large

institutions admitting non-residents. Similarly, deaths of residents dying outside the district should be included.

Correction for age and sex distribution is made by a "factor" obtained as below, which is greater than unity in nearly all towns, and less than unity in rural districts. Multiplying the local death-rate by the factor, the *corrected local death-rate* is obtained. The *comparative mortality figure* for the district is—

$$\frac{\text{corrected local death-rate}}{\text{death-rate for the whole country}} \times 1{,}000.$$

A *standard death-rate* for a locality is the death-rate for the whole country, re-calculated on the basis of the *local* age and sex distribution, and may be found as follows. The age and sex distribution per million of both local and general *population* are separately determined from census data as at page 618. The recorded *deaths* (in the whole country) are distributed in the same groups, and the number of deaths in each group corrected in the proportion of the local to the general population at those ages. If, for example, the males living at a given group of ages are x per million of the local population and y per million of that of the whole country, and the male deaths at those ages are m, the corrected number of deaths is $m \times \frac{x}{y}$. Adding together all the corrected numbers, we have a corrected total a, differing from the recorded total b (of deaths in the whole country), and representing the deaths which would have occurred had the age and sex distribution been the same as that of the locality. Hence $\frac{a \times 1000}{\text{population of whole country}}$ is the *standard death-rate* for the locality. The $\frac{\text{standard local death-rate}}{\text{death-rate of whole country}}$ is the factor sought, and is of course equal to $\frac{a}{b}$.

Urban death-rates are higher than rural, and the correction for age and sex distribution increases the inequality. The causes of this are complex, and include differences of occupation and mode of life, and the direct and indirect consequences of aggre-

On the other hand, there is a distinct increase in the mortality attributed to cancer, diabetes, suicide, and diseases of the nervous, circulatory, respiratory, and urinary systems. It is probable that some real increase has occurred in respect of nervous and circulatory diseases, and perhaps also urinary diseases, but improvement in diagnosis has also to be taken into account.

The cancer death-rate in 1861–70 was 387 per million, in 1871-80 473, in 1881-90 589; and a fairly well defined area in the counties of Lincoln, Northampton, Huntingdon, and Cambridge yielded exceptionally high rates. Age-distribution of population is important in this connection, since the mortality is chiefly at ages over 35. The increase is partly due to improved diagnosis, and to inclusion of forms of malignant disease not previously grouped with cancer. Recent researches in this country, while showing a wider difference among lower animals than had been suspected (*Bashford*), have not confirmed the suggestion that cancer is an infective disease due to micro-organisms. Instances are met with of repeated occurrence of the disease in "cancer houses," but little is known of dependence upon dietetic or other causes, and no special preventive measures are in force.

Zymotic death-rate is a term formerly applied to the aggregate death-rate from the "seven principal zymotic diseases"—small-pox, measles, scarlet-fever, diphtheria, whooping cough, "fever" (typhus, simple continued, and enteric), and diarrhœa. It is liable to great fluctuation, according to the epidemic prevalence of one or other of the diseases included. (*See* p. 600).

Deaths due to protracted sequelæ of acute specific diseases are usually credited to the secondary and not to the true primary cause. It will be found that the mortality from bronchitis and pneumonia is increased by outbreaks of influenza, whooping cough and measles, and scarlet-fever prevalence is followed by deaths referred merely to kidney diseases.

Sex has an important bearing upon the mortality from certain diseases, owing partly to differences in constitutional predisposition, and partly to exposure to the conditions favourable or unfavourable to the development of the diseases in question. The male mortality exceeds the female in most well defined diseases or groups of diseases, but there are im-

portant exceptions, such as diphtheria, whooping cough, erysipelas, rheumatism, cancer, and anæmia (including chlorosis and pernicious anæmia).

Age too materially affects the average liability to certain diseases, by reason of physiological changes, acquired protection, and degree of exposure. Vaccination completely alters the age-curve in small-pox. In all protective diseases the accumulation of protected survivors must be allowed for before any lessened average susceptibility at higher ages can be inferred. The maximum mortality from small pox, whooping cough, erysipelas, and diarrhœa occurs in the first year of life, from measles in the second, from scarlet-fever in the third, and from diphtheria in the fourth. A second maximum follows in small pox about the 25th year, and from about the same point diarrhœa mortality again rises until the end of life. Phthisis is at its minimum from the 5th to the 10th year, increases up to the 45th, and afterwards diminishes. Cancer mortality is small in the earlier years, but increases rapidly from about the 25th year to the end of life. The single curve, with a minimum from the 10th to the 15th year, which is characteristic of the total death-rate, is common also to the mortality from nervous, respiratory, digestive, and urinary diseases, and violence; diseases of the circulatory system increase steadily in mortality from birth to the end of life. The varying influence of age is seen even in infancy.

The true influence of sex and age cannot be ascertained by returns of mortality alone. The mere number of deaths at each age-period conveys little information, since the numbers living diminish as age advances. Even death-rates for each group tell only of the liability to death, but nothing as to the incidence of sickness or the chance of recovery. The variations in incidence and in severity, according to age and sex, are not always parallel, and indeed are often inverse, as in scarlet-fever and enteric fever. From the number of persons living, of each sex and at each age-period, it is possible to calculate, for

each sub-group, (1) the *incidence* of disease, that is, the proportion of attacks to population, and (2) the *case-mortality*, or proportion of deaths to attacks. Evidence as to incidence of disease at different ages can be obtained from notification returns, but hospital statistics are misleading, since age materially affects the chances of removal to hospital. As regards case-mortality, however, both hospital and notification data may be admitted.

Statistical evidence of the health of communities.—The usual criteria are either actual death-rates (general, "zymotic," or infant mortality) or figures representing the average longevity—namely, "expectation of life," "probable duration of life," "mean age at death."

The corrected *death-rate* affords a simple and, in the main, accurate measure of the comparative prevalence of disease. It is untrustworthy if the figures are so small as to be exposed to violent fluctuations; thus, the "weekly death-rate" is only useful in large communities. Other sources of error are (i) uncertainty as to population, and (ii) severe epidemics, which may have no known relation to impaired public health in general.

The *zymotic death-rate* is a popular but unsafe standard. A high death-rate from enteric fever, diphtheria, or diarrhœa may in general fairly be taken to imply a defective sanitary state; but may also be due to temporary and accidental causes, such as climatic conditions or accidental contamination of milk or water. Little is known of the determining causes of epidemics of small-pox, measles, whooping cough, and scarlet-fever; but their predisposing causes are all widely different, and are for the most part not affected by what are known as "sanitary conditions." The death-rate due to such a heterogeneous group denotes simply the presence or absence of grave epidemics, and connotes nothing as to the health condition of the community in other respects.

Infant mortality is influenced chiefly by the prevalence of epidemic diarrhœa in early autumn, by epidemics of whooping cough or measles, and by the want of proper care and management on the part of mothers. It is sometimes high in towns that have a low general death-rate; and a high infant death-rate cannot, therefore, be regarded as necessarily indicating a high tendency to death among the rest of the population. It is highest in those towns in which the causes of epidemic diarrhœa are operative, and, as a rule, high in districts where female labour is largely employed in manufactures.

The *phthisis death-rate*, if excessive, indicates dampness of soil, unhealthy occupations, or overcrowding of tenements. The death rate from respiratory diseases (other than phthisis) is also important.

The *mean age at death* is obtained by adding up the ages and dividing by the number of deaths. This is a very rough measure of longevity, largely controlled by the birth-rate, and by the age-distribution of the population. A high birth rate implies a large proportion of infant deaths, which must necessarily reduce the average age at death.

The *probable duration of life* is the age at which exactly half of any given number of children born will have died. It can only be ascertained from a life table, and is of no great value. The probable duration of life for males is about 51·2, and for females 56·7 years.

The *expectation of life*, at any age, is the average number of years which a person at that age will live, as shown by a life table. The expectation of life at age 0—*i.e.* at birth—is also known as the *mean duration of life.** At other ages than the time of

* The "mean duration of life" differs from the "probable duration of life" just as the arithmetical mean of a list of numbers differs from the

birth it is sometimes termed *mean after-lifetime*, and the present age *plus* the mean after-lifetime is the age to which a person may expect to survive.

The expectation of life is the true measure of the vitality of a community. The expectation at birth is the most convenient for comparative purposes, but if necessary we can eliminate the influence of infant mortality by taking the expectation at a later age.

A Life-table shows how many, out of a million persons supposed to be born simultaneously, will survive at the end of each year or each term of years. The data required are (1) a census population—that is, a population of which the distribution according to ages and sexes is known; (2) returns of deaths (grouped for each sex in the same age-periods as have been adopted for the census population) for one or more years among this same population. The simplest plan is to take only the deaths in the census year, when the population is known with precision; but as it is important to obtain large numbers, it is convenient to use the death returns of a series of three or more years, in which the census year is central. Thus the 1901 census population may fairly be assumed to be substantially the same as the average population in the years 1900-1-2. A still better method is to take the death returns for a whole inter-censal period, and the *mean* population. A separate table should be constructed for each sex.

Having decided upon the intervals to be taken (annual or quinquennial), the first step is to ascertain from the census returns the number living at each group of ages, and, from the death returns, the mean annual number of deaths among each group. As

middle value of the series. The fact that one term has as many terms above as below it does not render it the mean of the series.

The "mean duration of life" must also be carefully distinguished from the "mean age at death." The latter expression is not employed in reference to a life-table population.

already explained, $\frac{\text{number of deaths}}{\text{number living}} \times 1{,}000 = \text{D} =$ the death-rate for that group of ages per thousand living These D deaths (among 1,000 living) are assumed to be evenly distributed over the whole age-period included in the group, so that half $\left(i.e.\ \frac{D}{2}\right)$ will occur in the earlier half of the ages, and half in the later.* Hence the 1,000 persons are regarded as decreasing from $1{,}000 + \frac{D}{2}$ at the beginning of the period to $1{,}000 - \frac{D}{2}$ at the end of it; and the ratio of the final to the initial population is $\left(1{,}000 - \frac{D}{2}\right) : 1{,}000 + \frac{D}{2}$ or $\frac{2{,}000 - D}{2{,}000 + D}$. Having found the value of this ratio for each age or group of ages, we have all the data necessary for the construction of a life-table.

For the first year of life the formula is not required. If the infant mortality (deaths under 1 year of age per 1,000 births) be 200, it is evident that 1,000,000 persons at birth (*i.e.* living at the *commencement* of the year in question) will be reduced to 800,000 during the year. The number commencing the second year is 800,000; taking the death-rate during that year of age as 65 per thousand living, the formula becomes $\frac{2{,}000 - 65}{2{,}000 + 65}$, or $\frac{1{,}935}{2{,}065}$, and, as already explained the 800,000 living at the beginning of the second year will be reduced to $\frac{800{,}000}{1} \times \frac{1{,}935}{2{,}065}$, or 749,637 at its close. In like manner are determined the survivors

* In other words, "the number of the living in any year of their age is an arithmetical mean proportional between the numbers that annually enter upon and that annually complete that year" (Milne, quoted by Farr). An earlier hypothesis (De Moivre's) assumed that the numbers living decreased in arithmetical progression down to nothing at the age of *eighty-six years.*

at the end of the third, fourth, and fifth years. After the fifth year it is usual to proceed by quinquennial periods, but the method is substantially the same. Suppose, for instance, that we have already found that of the million only 700,000 survive at the end of the fifth year, and that the mean annual death-rate among persons aged five to ten years is [illegible]. This death-rate is assumed to be true of each of the five years, hence the formula of reduction for each year is $\frac{2,000 - r}{2,000 + r}$, and for the five years $\left(\frac{2,000 - r}{2,000 + r}\right)^5$. At the end of the tenth year, therefore, the 700,000 will have become reduced to $700,000 \times \left(\frac{2,000 - r}{2,000 + r}\right)^5$ —which by the aid of logarithms is readily found to be [illegible].

The process is repeated for each quinquennium until no more survivors are left.

If decennial be substituted for quinquennial periods, the annual death-rate r must be ascertained for the ten-year age period as a whole, and the formula will be $\left(\frac{2000 - r}{2000 + r}\right)^{10}$.

A life-table traces the history of a hypothetical generation which lives through each period of its life under the conditions that prevail (?) during the era under examination. It eliminates the disturbing influence of a variable birth-rate and migration-rate, which introduce many fallacies into any attempted estimation of longevity from mere death-rates in a changing population. A census return gives the numbers living at ages between certain fixed points; a life-table, on the other hand, shows the relative numbers surviving at certain points of time, or rather of age, and thus enables us to calculate the expectation of life at any such point.

The *expectation of life* at any age x is calculated

by adding together the years of life lived through by the whole of the life-table population after that age, and dividing by the number of survivors at age A. Thus to find the expectation of life at fifty years of age in males according to the 1881-90 life table (p. 620), the first step is to add together the numbers surviving at each later age: this gives the number of complete quinquennia lived through = 1,693,842. But in addition to the quinquennia which he completes, each of the 517,639 males surviving at age 50 lives through some portion of that quinquennium in which he dies. By a further application of Milne's principle this fraction is averaged as half a quinquennium, and hence we have to add 517,639 half-quinquennia to the 1,693,842 quinquennia. We thus get a total of 1,952,661·5 quinquennia or 9,763,307·5 years of future life; and this, divided among the 517,639 who are alive at age 50, gives the expectation of life as 18·8 years.

The expectation of life is somewhat greater among females than among males, at all ages. It is greatest in both sexes at about three years of age.

Seasonal variations.—Most diseases, and well-defined groups of diseases, have a fairly constant relation to season, and present characteristic curves of average seasonal mortality, subject, however, to variation in time and range in any given year. Many of them have an obvious relation to heat and cold; thus there is a winter maximum in deaths from apoplexy and diseases of lungs, heart, and kidneys; and a summer maximum as regards diarrhœa, tabes mesenterica, and thrush. Scarlet-fever, enteric fever, diphtheria, puerperal fever, erysipelas, and rheumatism have their maximum about November; small-pox and whooping cough have a spring maximum; and so, too, have phthisis, "convulsions," gout, and laryngitis. Measles has a double seasonal curve, with two maxima and two minima.

Cause of Death.	Mortality. Greatest.	Mortality. Least.
ALL CAUSES	(1) Dec. to March. (2) July to August.	(1) June. (2) October.
Small-pox	January to May.	Sept. and Oct.
Measles	(1) December. (2) June.	(1) September. (2) February.
Scarlet-Fever	October.	March to May.
Diphtheria	Nov., December.	May, June.
Whooping Cough	March, April.	Sept., Oct.
Enteric Fever	November.	June.
Typhus	January.	September.
Erysipelas	Nov., December.	May to Aug.
Puerperal Fever	November.	August.
Other deaths from childbirth	Dec., January.	June, July.
Diarrhœa	July (4th week), Aug. (1st and 2nd weeks).	Dec. to May.
Rheumatism	November.	August.
Alcoholism	July.	Dec. to Mar.
Gout	April.	September.
Phthisis	March, April.	September.
Apoplexy, Paralysis	Dec. to March.	July, August.
Convulsions	March.	September.
Diseases of Circulatory System	Nov. to January.	August.
Laryngitis	March.	Aug., Sept.
Bronchitis	January.	August.
Pneumonia	Jan. and March.	August.
Pleurisy	December.	August.
Kidney Disease	Nov. to April.	June to Aug.
Old Age	January.	June to Oct.

There are also characteristic seasonal curves of mortality from all causes at certain ages :—

Ages.	Mortality. Greatest.	Mortality. Least.
0-1	4th week in July to 2nd. week in Aug.	April, May, June .
1-5	(1) Feb. to April (2) July, August .	June, July . September . .
5-20	December . .	July, August .
Over 20	December . .	August . .

The mortality at ages from 5 to 20 shows only a slight excess at mid-winter and a slight falling off

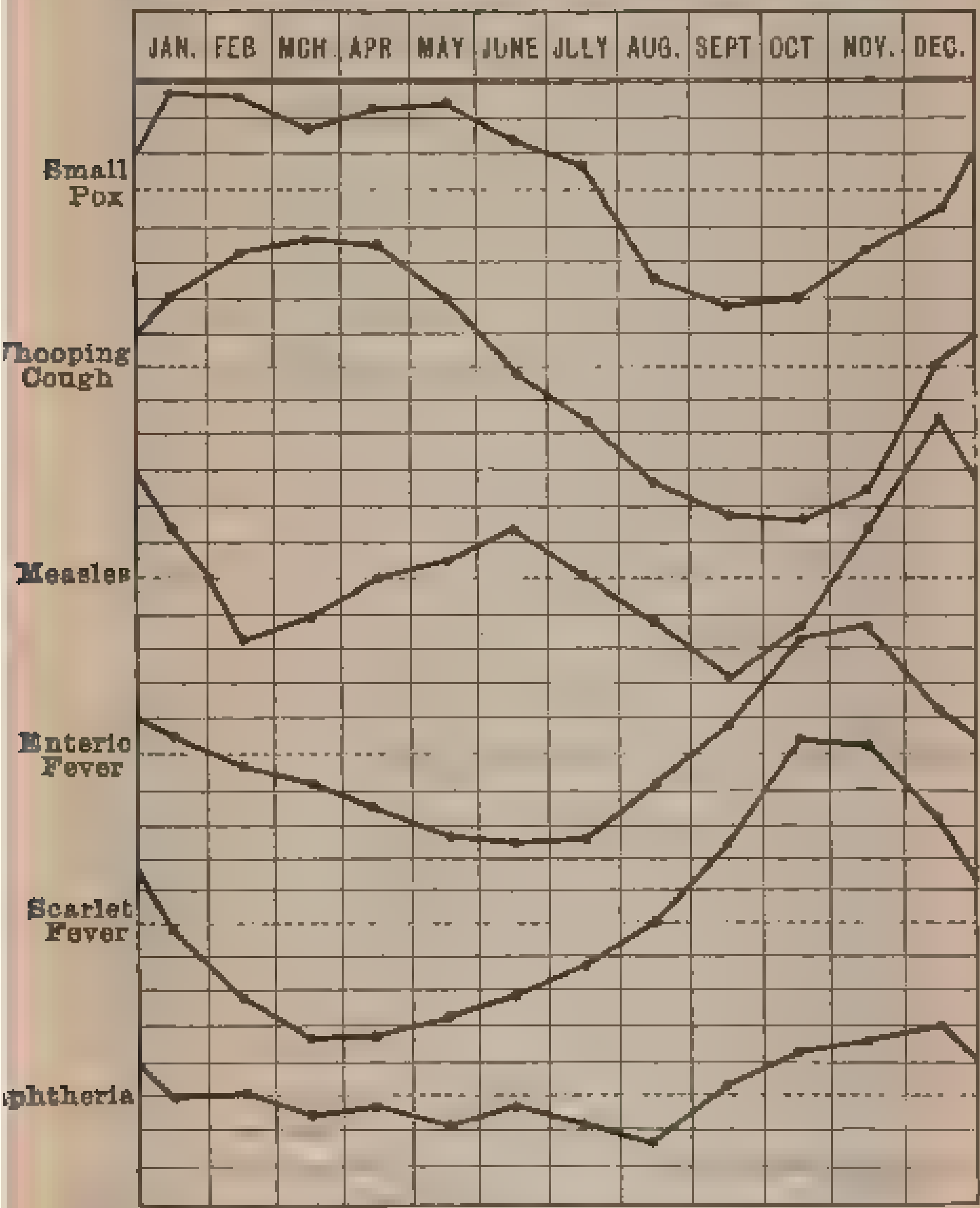

Fig. 23.—Seasonal Curves of Mortality (London): Mean of 40 Years, except Diphtheria (20 years) and Enteric Fever (12 years).

Each division corresponds to 10 per cent. above or below the mean annual mortality indicated by the dotted line.

at mid-summer. The position of the maximum and minimum points remains the same at all later ages, but a rapidly increasing sensitiveness to cold is manifested by a wider range of seasonal curve. Below five years of age a similar increase in sensitiveness to climatic conditions is found; but the greatest danger is from heat, not from cold. From one to five years the principal maximum occurs in the early spring, owing to seasonal prevalence of whooping cough and measles; but there is also a distinct rise in July and August, due to diarrhœal diseases. Under one year of age this minor elevation becomes an enormous peak, corresponding to the diarrhœa maximum.

Occupation and mortality.—In tracing, from mortality data, the influence of occupation upon health, it is necessary to make due allowance for sex- and age-distribution, as well as for the inevitable selection of the more robust for certain kinds of employment, and the weaker for others.

Comparing the results of the 1891 census with the mean mortality of the three years 1890–1–2, Tatham has shown that among the whole male population aged 25–65 the mean annual death-rate is 16·3, which may be alternatively stated as 1,000 deaths among 61,215 persons. The age-distribution of the 61,215 is that of the whole male population of the 25–65 age period, and it is found that there are 22,586 aged 25–35, 17,418 aged 35–45, 12,885 aged 45–55, and 8,326 aged 55–65. The rates of mortality from the several causes (such as phthisis, accident, etc.) can also be stated in figures the total of which is the 1,000 which represents the entire mortality.

In like manner the smaller statistics of persons engaged in different occupations are dealt with, and in order to arrive at comparable results the standard age- and sex-distribution has to be observed. Thus,

as regards the earthenware manufacture it is ascertained from the census returns how many male potters are living at each of the four age-decennia between 25 and 65, and from the death returns what is the annual number of deaths among male potters at each age decennium. It is then easy to calculate the annual number of deaths among 22,586 potters aged 25-35, 17,418 aged 35-45, 12,885 aged 45-55, and 8,326 aged 55-65, making up the standard population of 61,215. The sum of these deaths, which among "all males" was 1,000, in the case of the potters reaches 1,706. These are comparable

COMPARATIVE MORTALITY ACCORDING TO OCCUPATION, AMONG MALES 25-65 YEARS OF AGE.

England and Wales. 1890-91-92.	Phthisis.	Respiratory Diseases	Nervous Diseases.	Urinary Diseases.	Liver Diseases.	Circulatory Diseases.	Gout.	Alcoholism.	Plumbism	Suicide.	Accident.	Comp. Mort Figures.
ALL MALES	192	224	102	44	29	132	2	13	1	15	56	1000
Agriculturist	106	115	51	24	17	83	1	4	—	10	36	602
Fishermen	114	123	86	28	24	128	—	3		12	148	845
Cotton Manufacture	202	338	114	42	25	152	0	10	0	18	26	1141
Wool Manufacture	191	256	100	45	21	131	1	3	3	12	21	991
Coal Miners	97	269	67	30	17	120	0	4	0	9	141	925
Coal Heavers	215	472	98	50	37	221		29	—	7	144	1528
Tin Miners	508	377	99	45	28	95	—	4			48	1409
Lead Miners	380	425	62	41	34	142		5	5	5	43	1310
Glass Manufacture	293	445	155	63	30	157	9	24	12	17	59	1487
Earthenware	333	668	123	63	32	227	1	9	17	16	20	1706
Plumbers	217	224	131	84	22	142	10	13	19	16	52	1120
Lead Workers	148	397	232	161	80	272			211	13	45	1783
Cutlers	382	518	91	50	27	167	—	18	3	29	32	1516
File Makers	402	423	212	124	36	204	4	4	75	31	30	1810
Printers	326	214	98	52	30	133	4	10	3	17	19	1096
Tailors	271	195	98	46	31	121	1	12	0	15	22	989
Drapers	261	181	102	36	33	135		14		15	19	1014
Grocers	131	121	66	40	26	94	1	8		12	16	664
Bakers	185	207	69	49	39	130	1	11	—	19	25	920
Butchers	195	209	105	48	56	157	6	35		23	39	1096
Brewers	273	345	125	78	58	195	10	41	—	17	50	1427
Innkeepers	259	287	160	90	201	193	12	92	0	32	46	1642
Costermongers	443	403	139	70	29	222	3	36		14	64	1652
Dock Labourers	325	564	114	68	26	236	3	52	1	22	162	1829

figures, and in the same way comparable data as to mortality from phthisis and other special causes can be obtained for each occupation. A few examples are given on page 609.

The following list shows the comparative mortality figure, calculated in the same way, for a number of other occupations:—

ALL MALES	1,000	Blacksmiths	914
Occupied Males	953	Shoemakers	920
Unoccupied Males	2,215	Commercial Travellers	961
		Medical Men	966
		Shopkeepers generally	973
Clergy	533	Law Clerks	1,070
Gardeners	553	Hairdressers	1,099
Teachers	604	Hatters	1,109
Hosiery Manufacture	698	Musicians	1,214
Lace Workers	709	General Labourers	1,221
Tanners	756	Iron and Steel Manufacture	1,301
Artists	778		
Lawyers	821	Chimney Sweepers	1,311

Phthisis and respiratory diseases cause a high mortality among debilitated persons, especially those exposed to weather, to hot or impure air, and to certain forms of organic or inorganic dust. Hence the mortality from these causes is high among costermongers, cutlers, file-makers, potters, printers, and highest of all in Cornish tin-miners. The comparatively low mortality from phthisis among coal-miners may be attributed to the particles of coal being comparatively free from sharp angles and hence less irritating than stone or metallic dust (*Hirt*). The same immunity from phthisis has been observed among coal-miners in other countries, but it must not be forgotten that the nature of the employment excludes weakly persons, and that coal-mines are well ventilated.

Nervous diseases cause excessive mortality in occupations associated with alcohol or lead; the

most fatal occupations in this respect are those of innkeepers, glass-makers, file-makers, and lead-workers. The incidence of gout and of fatal kidney disease is very similar. Mortality from diseases of the liver is in the main associated with mortality from alcoholism, both being high, for example, among commercial travellers, butchers, brewers, and innkeepers. Suicide also has a fairly close relation to intemperance.

Diseases of the circulatory system are most fatal among costermongers, cabmen, brewers, publicans, potters, cutlers, file-makers, and workers in glass.

These figures tend to establish a relation between intemperance and diseases of the heart, liver, kidneys, and nervous system, and also phthisis, gout, and suicide. Lead poisoning, similarly, is seen to be associated with diseases of the kidney, heart, and nervous system, and also with gout.

Value of statistical series and averages.—The *mean* or *average* of a series of numbers is a number which lies between the greatest and least of these, and stands in a definite dependence upon the whole of the series (*Radicke*). There are several kinds of means. Thus, if the series consists of four numbers—namely, a, b, c, and d—we have

The *arithmetic* mean, or simple average, $\dfrac{a+b+c+d}{4}$.

The *geometric* mean, $\sqrt[4]{a\,b\,c\,d}$.

The *harmonic* mean, $\dfrac{4}{\frac{1}{a}+\frac{1}{b}+\frac{1}{c}+\frac{1}{d}}$

The *quadratic* mean, $\sqrt{\dfrac{a^2+b^2+c^2+d^2}{4}}$.

When the terms of the series are equal, all kinds of means are also equal; but if otherwise, the quadratic

is the highest, then the arithmetic, geometric, and harmonic, in the order stated.

The simple average, or arithmetic mean, is by far the most generally adopted, and mainly in three classes of cases :—

1. *As a pure average;* for example, the average age of a number of persons. The terms are exact, and the "mean" has no significance as regards any individual. Thus, the ages of ten persons whose deaths were attributed to diarrhœa might be 1, 1, 1, 1, 71, 71, 1, 1, 1, 71 ; and those of ten who died from enteric fever 17, 18, 26, 29, 25, 20, 16, 19, 24, 26. These two series have nothing in common as regards the individuals, but the average of each is 22. The mean temperature of a day or year is a simple average of the observations which are taken into account. Similarly, if we mix together equal volumes—say, an ounce of each—of four saline solutions containing respectively 10, 20, 30, and 40 grains of salt per ounce, the whole will contain 25 grains per ounce.

2. *As a probable true value of a definite quantity.*—Given two results equally likely to occur, the frequency of the one becomes more and more certainly equal to that of the other, in proportion as the number of observations increases. If a coin be tossed 1,000 times, it is improbable that heads will turn up much more or much less than 500 times ; but with only 10 trials, there is little certainty of approximate equality. If in a given series of measurements of a fixed quantity (an angle, for instance), the errors of experiment are exactly as likely to be in excess as in deficiency, these errors will neutralise each other if we take the mean of a sufficiently large number of observations. An error of magnitude x in a single observation will affect the mean to the extent $\frac{x}{10}$ in a series of ten ob-

servations, but only $\frac{x}{1{,}000}$ in a series of a thousand terms. The more extended the series, the greater the probability of accuracy, which increases as the square root of the number of observations.

If the measurements are of equal precision, a closer but less simple approximation to the probable true value sought may be obtained by adopting the principle of *least squares*: that is, by finding such a mean value that the sum of the squares of the residual errors of the observations shall be a minimum.

3 *As a probable value of a variable quantity* determined under average conditions; for example, the average daily excretion of urea, as determined by a series of more or less exact measurements under varying conditions as to food and exercise. In vital statistics absolutely fixed points are of rare occurrence, and most of the problems belong strictly to this class.

It may be important to determine the value of a series of observations; that is, how far the mean is a trustworthy approximation to the true value sought. As already explained, the value of a series increases with the number of observations, and with their equality. Another test is that of "*successive means.*" For this purpose we take the mean of the first two terms $\left(\frac{a+b}{2}\right)$, of the first three $\left(\frac{a+b+c}{3}\right)$, of the first four $\left(\frac{a+b+c+d}{4}\right)$, and so on. These "successive means" may vary sharply at first; but presently the first figure becomes stationary; then the second; and finally, if the series is sufficiently extended, the later successive means cease to vary materially. If the successive means, carried to the end of the series of terms, do not attain the required degree of constancy, the series is too short.

A further criterion is the determination of the

error; that is, the divergence of the individual terms of the series from its mean. The *mean error in excess* and the *mean error in deficiency* are simply the arithmetic means of the errors of those terms which fall respectively above and below the mean of the series. The *mean error of the series* is the average of the mean errors in excess and deficiency. The greater the mean error, the greater is the need for an extended series in order to compensate for the uncertainty of each observation. Radicke prefers to adopt the quadratic mean error rather than the arithmetic, described above, since the former increases more rapidly with the inequality of the terms.

Multiplying the mean error by ·6745 or $\frac{2}{3}$ we get the *probable error*, so called because it is probable that, if the series were prolonged indefinitely, the errors would as often exceed as fall short of this quantity.

The *maximum error*, whether in excess or deficiency, is useful as showing the *possible* error of a limited number of observations. Another way of estimating the error is to determine the "*error of mean square.*" In a series of n terms, Q being the quadratic mean and A the arithmetic mean, the "error of mean square" is $\frac{Q-A}{(n^2-n)}$.

The value of a series increases as the proportion of the "error" (of whatever kind) to the mean diminishes. The relative values of two or more series vary inversely as the square of their "probable errors."

Statistics are often presented in bulk, and the same question of sufficiency arises. For instance, out of 6,288 reported cases of scarlet fever 2,861 are at ages under five years; are these numbers sufficiently great to warrant the conclusion that the proportion, 45·5 per cent., is approximately constant? Such data are really the sum or average of suppressed series, and

their value is proportionate to the square root of their magnitude. *Poisson* proposed to measure the liability to error thus:—If of μ observations, m are in one category and n in other categories, and $m + n = \mu$, then the true proportion of the m category to the total μ lies between $\frac{m}{\mu} + 2\sqrt{\frac{2mn}{\mu^3}}$ and $\frac{m}{\mu} - 2\sqrt{\frac{2mn}{\mu^3}}$, that is, within a possible range of $4\sqrt{\frac{2mn}{\mu^3}}$. In the instance in point the range is $4\sqrt{\frac{2 \times 2,861 \times 3,427}{(6,288)^3}}$, or about $\frac{36}{1,000}$. Hence the indicated proportion, 45·5 per cent., is liable to a range of error of 3·6 per cent., from 43·7 to 47·3.

It may also be possible to divide the total μ into two or more fairly equal parts, and thus ascertain if the proportion $\frac{m}{\mu}$ is approximately constant in each. Such constancy would tend to show that the proportion is a fixed quantity, and not a mere average.

The preceding remarks have reference mainly to series that are intended to show by their mean some true fixed quantity. Sometimes they are used for a different purpose—namely, the exhibition of progressive changes or fluctuations. Here the general considerations as to magnitude still apply, but the determinations of "error" have no significance except in regard of the individual terms of the series. It is often convenient, for the purpose of comparing the fluctuations of different series, to adopt *Buchan and Mitchell's method*—namely, to state each term of a series as a percentage of the arithmetic mean of the series. In this way all series, whether the terms are large or small, are reduced to the same scale, and their true differences and resemblances can be seen at a

glance. The curves in Fig. 23 may serve as an example.

If the terms of a series are based upon scanty statistics, the accidental irregularities may be so great as to obscure the true curve. Some degree of this is evident in respect of diphtheria in Fig. 23. A clearer indication of the general outline may in such cases often be obtained by *Bloxam's method*—that is, by substituting for each term the mean of three adjoining terms. Thus in a series a, b, c, d, e, f, g, etc., we should substitute (a), $\frac{a+b+c}{3}$, $\frac{b+c+d}{3}$, $\frac{c+d+e}{3}$, etc. This treatment is, of course, arbitrary, and curves so constructed are not to be regarded as exact in detail.

APPENDICES.

I. Urban and Rural Birth and Death Rates, 1881—90. England and Wales.

Rates.	Large Towns.		Rest of Country.	England and Wales.
	28 Great Towns.	50 Other Towns.		
Birth Rate	34·0	33·7	31·2	32·3
Infant Mortality ..	162	153	128	142
Death Rate—				
All Causes ...	21·6	19·7	17·6	19·1
Small Pox... ...	0·09	0·03	0·02	0·05
Measles	0·63	0·50	0·33	0·44
Scarlet Fever ...	0·40	0·39	0·29	0·33
Whooping Cough	0·61	0·42	0·37	0·45
Diphtheria ...	0·19	0·10	0·16	0·16
Diarrhœa... ...	0·89	0·73	0·52	0·66

II. Death Rates at Ages, England and Wales.

Ages.	Males.					Females.				
Ten years ended	1860	1870	1880	1890	1900	1860	1870	1880	1890	1900
All Ages	21·9	22·9	21·5	19·7	19·2	20·6	20·4	19·3	17·6	17·0
0—5	72·7	73·5	68·6	61·6	62·7	63·0	65·7	58·4	52·0	52·8
5—10	8·5	8·2	6·7	5·4	4·3	8·4	7·8	6·3	5·3	4·4
10—15	4·9	4·6	3·7	3·0	2·4	5·1	4·5	3·7	3·1	2·6
15—20	6·7	6·2	5·3	4·3	3·8	7·4	6·7	5·5	4·4	3·7
20—25	8·8	8·6	7·4	6·7	5·1	8·6	8·0	6·3	5·5	4·5
25—35	9·6	9·9	9·4	7·8	6·8	10·0	9·7	8·6	7·4	6·1
35—45	12·5	13·5	13·8	12·4	11·5	12·2	12·1	11·3	10·5	9·6
45—55	18·0	19·2	20·1	19·4	19·0	15·3	15·6	15·6	15·1	14·8
55—65	31·0	33·1	34·9	34·7	35·0	27·1	27·9	28·7	28·5	28·5
65—75	65·5	67·1	69·7	70·4	70·4	58·9	59·1	61·0	60·4	60·7
75—85	146·7	147·2	150·8	146·6	140·1	134·5	134·9	135·4	130·0	130·6
Over 85	308·2	315·0	327·4	305·8	286·2	286·0	285·1	296·4	270·8	261·4

III. POPULATION.—ENGLAND AND WALES.

Census.	Population.	Rate of Decennial Increase.	Females per 100 Males.	Density.	
				Per Square Mile.	Per Inhabited House.
1861	20,066,224	11·9	105·3	344	5·4
1871	22,712,266	13·2	105·4	390	5·3
1881	25,974,439	14·4	105·5	445	5·4
1891	29,002,525	11·7	106·4	497	5·3
1901	32,526,075	12·2*	106·9	558	5·2

* Highest (23·1) in urban districts of 50,000 to 100,000, diminishing in each direction to 9·3 in those over 250,000 and to 4·6 in those under 3,000.

IV. AGE AND SEX DISTRIBUTION OF POPULATION PER MILLION, ENGLAND AND WALES, CENSUS 1901.

Age-Periods.	Males.	Females.	Total.	Urban.	Rural.
0—5	57,089	57,223	114,262	114,348	113,978
5—10	53,462	53,747	107,209	105,555	112,760
10—15	51,370	51,365	102,735	101,147	108,397
15—20	49,420	50,376	99,796	101,080	95,489
20—25	45,273	50,673	95,946	100,291	81,870
25—35	76,425	85,154	161,579	167,597	141,390
35—45	59,394	63,455	122,849	124,282	118,039
45—55	42,924	46,298	89,222	88,368	92,086
55—65	27,913	31,828	59,741	56,642	70,139
65—75	14,691	18,389	33,080	29,502	45,080
75—85	5,080	7,010	12,090	10,102	18,758
Over 85	552	939	1,491	1,186	2,514
All Ages	483,543	516,457	1,000,000	1,000,000*	1,000,000†

* Males, 479,444; females, 520,556.
† Males, 497,293; females, 502,707.

V. BIRTH RATES AND DEATH RATES, ENGLAND AND WALES.

Decennium.	Birth Rate.	Births of Males per 100 Births of Females.	Death Rate.			Infant Mortality.
			Male.	Female.	Total.	
1851—1860	34·1	104·6	23·0	21·3	22·4	154
1861—1870	35·2	104·2	23·6	21·3	22·4	154
1871—1880	35·5	103·8	22·6	20·0	21·3	149
1881—1890	32·4	103·7	20·2	18·0	19·1	142
1891—1900	29·9	103·6	19·3	17·2	18·2	154

VI. DEATH RATES PER MILLION, ENGLAND AND WALES.
CAUSES AND 5-YEAR PERIODS.

CAUSES. Five years ending	1875	1880	1885	1890	1895	1900
All Causes	21,962	20,791	19,403	18,895	18,718	17,685
Small Pox	411	78	78	14	20	7
Measles	878	885	418	408	407	421
Scarlet Fever	759	680	436	241	182	135
Typhus	81	34	23	7	4	1
Enteric Fever	374	277	216	179	174	175
Whooping Cough	495	527	459	444	398	359
Diphtheria	121	122	156	179	253	272
Diarrhœa	1,081	853	672	681	651	817
Pneumonia	1,025	999	1,062	1,181	1,25[illegible]	1,203
Erysipelas	106	61	83	54	48	35
Phthisis	2,218	2,040	1,830	1,635	1,462	1,322
Alcoholism	38	42	48	56	68	80
Rheumatic Fever	(?)	62	98	89	88	83
Cancer	446	494	548	632	711	800
Diabetes	36	40	51	62	69	81
Premature Birth	447	473	475	507	502	574
Heart	(?)	2,475	2,383	2,581	2,504	2,417
Bronchitis	2,221	2,377	2,154	2,136	2,074	1,669
Cirrhosis of Liver	72	110	120	122	120	135
Bright's Disease	137	188	222	248	257	278

VII. DEATH RATES PER MILLION, ENGLAND AND WALES, 1881–90.
CAUSES AND AGES.

CAUSES. Ages	0–5	5–10	10–15	15–20	20–25	25–35	35–45	45–55	55–65	65–75	Over 75
Small Pox	80	33	26	41	50	67	44	32	21	17	20
Measles	3131	27[illegible]	23	7	6	0	4	2	1	1	1
Scarlet Fever	1609	762	153	41	26	22	12	4	2	3	1
Typhus	4	7	2	16	17	18	20	21	17	12	6
Enteric Fever	128	180	208	289	282	232	182	155	142	113	62
Whooping Cough	3370	128	4	1	1	0	0	0	1	1	3
Diphtheria	690	424	100	36	20	17	16	14	17	17	12
Diarrhœa	4340	54	16	15	23	37	61	107	301	905	2581
Pneumonia	3668	208	119	201	301	404	833	1157	1762	2560	3187
Phthisis	536	200	521	1545	2824	2901	3139	2787	2169	1[illegible]55	621
Cancer	20	10	11	20	55	125	584	1546	2808	4100	4205
Diabetes	4	7	15	24	30	46	64	107	217	2[illegible]3	238
Bronchitis	7497	182	40	44	67	159	520	1549	4418	10795	23226
Diseases of—											
Nervous System	8337	578	320	331	333	501	1098	2109	4972	1[illegible]827	21665
Circulatory	[illegible]34	149	298	334	358	592	1345	257[illegible]	5712	[illegible]	18864
Digestive	2962	225	161	204	237	353	747	142[illegible]	29[illegible]0	4443	6786
Urinary	103	99	62	69	188	226	437	734	[illegible]	2880	[illegible]

VIII. Death Rates per Million, England and Wales, 1881—90. Causes and Sex.

Causes.	Male.	Female.	Causes.	Male.	Female.
All Causes ...	20,218	18,006	Pneumonia ...	1,275	868
			Phthisis	1,847	1,609
Small Pox... ...	52	38	Cancer	430	739
Measles	468	414	Diabetes	69	45
Scarlet Fever .	346	322	Bronchitis .	2,320	2,060
Typhus ...	16	13	Diseases of—		
Enteric Fever ...	211	182	Nervous System	2,604	2,392
Whooping Cough	418	480	Circulatory ,,	1,648	1,602
Diphtheria ...	158	167	Digestive ,,	1,147	1,064
Diarrhoea	728	628	Urinary ,,	556	318

IX. English Life Table, Based upon the Statistics of 1881–90 (Tatham).

Age.	Males.				Females.			
	Survivors at each age, out of 1,000,000 born.	Expectation of Life.			Survivors at each age, out of 1,000,000 born.	Expectation of Life.		
		1881-90	1871-80	1838-54		1881-90	1871-80	1838-54
0	1,000,000	43·7	*41·4*	*39·9*	1,000,000	47·2	*44·6*	*41·9*
1	838,964	51·0	*48·1*	*46·7*	868,874	53·2	*50·1*	*47·3*
2	790,891	53·0	*50·1*	*48·8*	823,072	55·2	*52·2*	*49·4*
3	772,046	53·3	*50·9*	*49·6*	804,142	55·5	*53·0*	*50·2*
4	760,167	53·2	*51·0*	*49·8*	791,973	55·3	*53·2*	*50·4*
5	751,494	52·8	*50·9*	*49·7*	783,244	54·9	*53·1*	*50·3*
10	733,477	49·0	*47·6*	*47·1*	766,151	51·1	*49·8*	*47·7*
15	726,194	44·5	*43·4*	*43·2*	759,062	46·6	*45·6*	*43·9*
20	712,555	40·3	*39·4*	*39·5*	744,321	42·4	*41·7*	*40·3*
25	693,809	36·3	*35·7*	*36·1*	724,788	38·5	*38·0*	*37·0*
30	669,279	32·5	*32·1*	*32·8*	700,049	34·8	*34·4*	*33·8*
35	639,645	28·9	*28·6*	*29·4*	670,992	31·2	*30·9*	*30·6*
40	604,923	25·4	*25·3*	*26·1*	638,912	27·6	*27·5*	*27·3*
45	564,437	22·1	*22·1*	*22·8*	604,007	24·1	*24·1*	*24·1*
50	517,639	18·8	*18·9*	*19·5*	564,299	20·6	*20·7*	*20·8*
55	462,981	15·7	*16·0*	*16·5*	516,375	17·2	*17·3*	*17·4*
60	398,400	12·9	*13·1*	*13·5*	457,682	14·1	*14·2*	*14·3*
65	322,482	10·3	*10·6*	*10·8*	385,503	11·3	*11·4*	*11·5*
70	238,632	8·0	*8·3*	*8·5*	299,220	8·8	*9·0*	*9·0*
75	153,896	6·1	*6·3*	*6·5*	204,208	6·7	*6·9*	*6·9*
80	80,023	4·5	*4·8*	*4·9*	114,536	5·0	*5·2*	*5·3*
85	29,866	3·3	*3·6*	*3·7*	48,133	3·7	*3·9*	*4·0*
90	6,786	2·4	*2·7*	*2·8*	13,418	2·8	*2·9*	*3·0*
95	752	1·7	*2·0*	*2·2*	2,124	2·1	*2·2*	*2·3*
100	30	1·2	*1·6*	*1·7*	157	1·5	*1·6*	*1·8*

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